Assessment of Safety Level in Performing Building Maintenance Work in Saudi Arabia

by

Waleed A. Al-Amoudi

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

June, 1997

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UMI Number: 1390289

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

COLLEGE OF GRADUATE STUDIES

This thesis, written by WALID A. AL-AMOUDI under the direction of his Thesis Advisor and approved by his Thesis Committee, has been presented to and accepted by the Dean of College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING & MANAGEMENT.**

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25/4/98
Date

This thesis is dedicated to

- My mother and father

- My wife

- My kids Rayan, Amjaad and Habah

- And to all other members of my family

ACKNOWLEDGMENT

Acknowledgment is due to King Fahd University of Petroleum and Minerals for support of this research.

I wish to express my appreciation to Professor M. Osama Jannadi who served as my primary adviser. I also wish to thank the other members of my thesis committee; Professors Sadi Assaf and Ellahi Ishteeaque from the Department of Construction Engineering and Management.

My sincerest appreciation to all the maintenance industry representatives whose information gained through a questionnaire survey provided me with the necessary research data.

I express my gratitude to my wife for her encouragement, patience and support, without which this work would not have been possible.

THESIS ABSTRACT

NAME OF STUDENT	:	WALEED AHMAD AL-AMOUDI
TITLE OF THE STUDY	:	ASSESSMENT OF SAFETY LEVEL IN PERFORMING BUILDING MAINTENANCE WORK IN SAUDI ARABIA
MAJOR FIELD	:	CONSTRUCTION ENGINEERING AND MANAGEMENT
DATE OF DEGREE	:	JUNE 1997

This thesis presents the results of research assessing the safety level in performing building maintenance work in Saudi Arabia. To perform this objective a survey was distributed among 430 building maintenance contractors in the Eastern Province of Saudi Arabia. In this research, the population of contracting firms was divided into three categories according to the firm size (small, medium, and large).

The survey consists of two parts. The first part contains general information and this includes the total number of disabling injuries, and the total work order hours were used to calculate the frequency rate. The second part contains 42 safety factors relevant to contractor safety which were used to measure the contractors' safety attitudes. The safety factors were ranked by their level of importance based on the survey results. It was determined that small, medium and large contractors do not agree on the ranking of the different safety factors. In addition, the contractors' frequency rates and contractors' safety attitudes determinants were used to measure the safety performance level for building maintenance contractors.

Finally, statistical correlation was used to investigate and examine the relationship between the frequency rates and the safety attitudes scores for each size of contractor. It was concluded that a negative slope linear relationship exists between the frequency rates and safety attitudes, and large contractors have the highest correlation between the frequency rates and contractor safety attitudes. This linear relationship could be a useful tool in the prediction of one variable from the other using a linear equation.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN - SAUDI ARABIA

خلاصة الرسالة

اسم الطالب	:	وليد أحمد عبدالقادر العامودي
عنوان الدراسة	:	تقييم مستوى السلامة في تنفيذ أعمال صيانة المباني في المملكة العربية السعودية .
التخصص	:	ادارة وهندسة التشييد
تاريخ الشهادة	:	يونيو ، ١٩٩٧م

تستعرض هذه الرسالة نتائج البحث والتحليل لتقييم مستوى السلامة في تنفيذ أعمال صيانة المباني في المملكة العربية السعودية . ولتحقيق هذا الهدف ، فقد تم توزيع استبيان على (٤٣٠) أربعمائة وثلاثون مقاول صيانة في المنطقة الشرقية من المملكة العربية السعودية وفي هذا البحث تم تقسيم المقاولين إلى ثلاثة أقسام طبقاً لحجم المقاول (صغير ، وسط ، كبير) .

وقد تكون الإستبيان من جزئين . الجزء الأول احتوى على معلومات عامة كعدد الجرحى الغير قادرين على العمل ومجموع أوقات أوامر العمل خلال السنة . الجزء الثاني احتوى على (٤٢) اثنان وأربعون معياراً من معايير السلامة التي لها علاقة بسلامة المقاول كنتيجة أولية لهذا الاستبيان، وقد تم ترتيب تلك المعايير حسب أهميتها.وكذلك استخدم معدل تكرار الحوادث ، والإدراك الحسي للسلامة في تقييم مستوى السلامة بالنسبة لمختلف أحجام المقاولين .

وقد ظهر من تحليل الإستبيان أن معايير السلامة المهمة لحجم معين من المقاولين تختلف بالنسبة للحجمان الآخران من المقاولين كما يختلف ترتيبها من حيث الأهمية من حجم إلى آخر وأن مستوى السلامة في قطاع صيانة المباني يختلف بإختلاف حجم المقاول . وقد بين البحث أيضاً العلاقة بين معدل تكرار الحوادث والإدراك الحسي للسلامة بالنسبة لمختلف أحجام المقاولين .

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CHAPTER 1

THE NEED FOR ASSESSMENT OF SAFETY PERFORMANCE

1. INTRODUCTION

During the last few years the Kingdom of Saudi Arabia has undergone a phenomenal phase of development in almost every sphere of life. Consequently it has now acquired a relatively large and complex infrastructure both in the public and private sectors. The size of this infrastructure is well documented in the many publications by both government and non-government organizations. Its complexity is evident in the high technology employed, and in the geographic spread of modern systems. Making full use of this infrastructure requires its efficient operation and introduction of sound safety maintenance practices.

Maintenance contractor safety practices are important for many reasons (Nicole, 1988):

1. Humanitarian reasons : Safety protects people's lives

2. Government regulations: Most cities and provinces in Saudi Arabia have safety laws and regulations of some kind. Typical safety regulations and fire codes are commonly issued and administered by the municipality and interior ministry or civil defense. Most of the regulations deal with the structural safety of buildings and with safety in

construction and operations. These regulations govern the issue of building license or permit. Some of these regulations are (Brauer, 1990):

a. The fire department enforce the building designer to include safety requirements in the architectural design of the building so that maintenance work will have safer environment. An example of safety regulation enforcement is clear in the buildings of the central area in Almadinah Almunawrah which have been designed, constructed and operated with a high level of safety standard.

b. Government Request contractor to develop and implement safety programs: there are many elements of a safety program that are essential to its success. Some are required by law and others vary with the structure and operations of contractor organizations.

c. Government Emphasize safety as a contractor responsibility and safety policy: a safety program must clearly identify who is responsible for what. Assignment of responsibility is normally a part of policy and procedures.

d. Government Enforce contractor commitment to safety: for safety to be an effective program, there must be a commitment at the highest level. That commitment must include a clear statement that safety is important and support for actions that will make safety important.

e. Government Identify hazards to be recognized and controlled: identification of hazards may be associated with new or modified operations, equipment or facilities. Inspections or periodic review of operating procedures will help identify hazards and whether controls for them are in place and in use. For example, there should be inspections of repair and maintenance work to ensure the guards are replaced or an area is clear of sources of heat and fire.

f. Communicate with employees concerning their responsibilities for working safely: workers must learn about the hazards related to their job and the means for protecting themselves and how to perform particular safety procedures.

3. Accidents affect public relations
4. Accidents may affect operations
5. Accidents cost money and
6. Productivity is increased with improved safety performance.

1.1. STATEMENT OF THE PROBLEM

Safety practices and regulations are important in the maintenance industry. However, as in other types of industry, it is unknown to what extent contractors comply with safety practices and regulations.In addition, there is a lack of knowledge of variables that can be used to assess the safety level of building maintenance contractors.

1.2 OBJECTIVE OF THE STUDY

The objectives of this study are as follows:

1. To determine the most important safety factors that affect the performance of building maintenance contractors.
2. To measure the accident frequency rate and the safety attitude score for building maintenance contractors.
3. To assess the safety performance level among building maintenance contractors.
4. To describe the variability in the accident frequency rates and the safety attitude scores for building maintenance contractors.
5. To conduct a correlational analysis to find how variation in frequency rates is related to variation in safety attitude scores.

1.3 THE SIGNIFICANCE OF THE STUDY

This study was conducted mainly to find the most important factors that affect building maintenance contractors. Beside that, knowing the accident frequency rate of contractors and their safety attitude provide an important variable for predicting one from the other.

The results of this study will be very useful in evaluating the safety level of maintenance contractors during the bidding process or during the contract period.

CHAPTER 2

DESCRIPTION OF SAFETY LEVEL OF ASSESSMENT OF BUILDING MAINTENANCE CONTRACTORS IN SAUDI ARABIA.

2.0 INTRODUCTION

Safety assessment is a process used to determine a contractor's compliance with or ability to meet specific safety rules and requirements set by the government safety regulations or by safety and environmental organizations. Safety rules or criteria are needed to accomplish the work with high overall performance. Any deviation from these safety requirements will affect the contractor's overall performance.

2.1 PREVIOUS STUDIES

Safe acts and safe conditions in performing maintenance and construction works have been receiving broad attention in the safety engineering and management literature.

Duff, Robertson, Phillips and Cooper (1994) conducted a study in the development and effects of behaviorally based management techniques in improving site safety. Goal-setting and feedback methods were developed and tested on six construction sites. Measures of safety performance were taken before, during and after the application of these methods. The result shows that safety behavior can be objectively and reliably measured, without excessive use of managerial or supervisory resources, producing performance data that can be used in many different safety management strategies, which will produce large improvements in safety performance. Also, it shows that the commitment of the site management appears to enhance the effectiveness of the goal setting and feedback approach.

Geller[1](1995) wrote in his article that:

> "safety coaching is a key process in developing a total safety culture. The more employees effectively apply safety coaching principles, the closer an organization will be to achieving total safety culture. Beyond training and practice to develop coaching skills, the work culture must enable and support interpersonal coaching. In addition, those who receive coaching need to express appreciation for feedback received."

Geller[2] (1994) wrote in his article that:

> "behaviors which reduce the probability for injury often involve environmental change and produce attitudes consistent with the safe behaviors, especially if these behaviors are viewed as voluntary. In

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1. Geller, E. Scott, "Safety Coaching". Professional Safety, July 1995, P.17.

2. Geller, E. Scott, "Ten Principles for Achieving a Total Safety Culture". Professional Safety, Sept. 1994, P.19

> other words, when employees choose to act safely, they act themselves into safe thinking, such behaviors often result in some environmental change."

Giustina, J and D. Giustina (1989) conducted a research study on quality of work life through employee motivation. The findings of this study illustrated three important contributions management can offer employees to improve safety in the workplace:

1) Knowledge and understanding of safe and healthy work practices: employees must be trained to identify present and potential hazards not only in the job they are performing, but in jobs being performed nearby.

2) A strongly shared belief that top management is truly committed to safety and health: workers must know that top management is willing to devote resources to improve safety and health in the workplace.

3) Management's recognition and support for changes in work behavior to achieve the desired safe work behaviors will stimulate workers to take responsibility for change.

Harner[1] (1983) wrote in his article that

> "management is what management does. Commitment without involvement is meaningless. Good attitude is related to and depends upon the involved commitment of management. Involvement means at least occasional attendance by all levels of management, at safety meetings. Involvement is participation by management, in accident investigations. Involvement includes visibility and exhibiting a concern for their employee's safety and health."

Heinrich (1959) has studied the contribution of both unsafe acts and unsafe conditions. He analyzed 75,000 accidents and found that 88% were caused by unsafe acts or unsafe operation, 10% from unsafe conditions or unsafe work locations, and 2% from unpreventable causes (Baruer, 1990).

Hidley and Krause[2] (1994) wrote in their article that

> "managing safety for continuous improvement requires a behavior-based, rather than attitude-based, process. Signature features of a behavior-based approach to safety are:

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1. Harner, "Safety is a Duty of Management, Labor and Government". Professional Safety, Nov. 1983, P.14

2. Hidley, J.H. and T.R. Krause, "Paradigm Shift Beyond the Failures of Attitude-Based Program". Professional Safety, Oct. 1994, P.29.

- behaviors are systematically identified and operationally defined;
- systematic observation of critical behaviors;
- safety data are analyzed to prevent accidents;
- employee involvement in problem solving and action planning. on the basis of observation data;
- subsequent observation and feedback on new measures."

Hinze, Bern and Piepho (1995) conducted a study of the importance of Experience Modification Rating (EMR) as a measure of safety performance. This rating is used to adjust the cost of workers' compensation insurance premiums. This modifier is essentially an incentive for firms to strive for good safety records, as firms with poor safety records will pay higher premiums. Results show how frequency rate has a larger impact on the EMR than does severity rate. The EMR is noticeably reduced when hourly wages paid are increased. It is also reduced when the total wages paid per year are increased. Findings suggested that the EMR is not an appropriate measure of safety performance for all companies.

Jannadi and Assaf (1990) assessed the safety practices in different job sites in Saudi Arabia with varying project sizes using a standard ARAMCO checklist. They found that safety level in job sites varies with the project size. Large projects have better average safety level than small projects. They concluded that the safety level is mainly related to the nationality and the type of the project. The assessment results showed that there is a need for a safety code in Saudi Arabia which should be strictly applied to protect workers and property.

Johnson[1] (1988) discussed Management accountability for safety performance. He wrote in his article that:

> "management accountability must be directed toward loss prevention rather than loss reduction. This accountability could be measured with safety audits, inspection results, safety sampling, development of accident reduction goals, and safety performance reviews."

Kibert and Coble[2] (1995) wrote in their article that:

> "integrating safety and environmental regulation would provide a single agency that would eliminate conflicts, duplication of regulations and information, and increase efficiency and quality of worker safety and environmental protection. There are also significant cost savings by combining the various safety and environmental regulatory functions."

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1. Johnson, Stephen, "Management Accountability for Safety Performance". Professional Safety, June 1988, P.22.

2. Kibert, C.J. and Richard J. Coble, "Integrating Safety and Environmental Regulation of Construction Industry". Journal of Construction Engineering, March 1995, P.96.

Krause and Russell[1] (1994) wrote in their article that:

> "the behavior-based approach integrates accident investigation data with other relevant data. The primary behavioral recommendation is to include the injured person on the investigating team. Guided by principles of scientific analysis, behavior-based investigating and interviewing procedures focus on fact finding, which is aimed at preventing future incidents rather than on discipline and fault finding."

Lateiner (1969) conducted a study of the importance of attitude in controlling incidents and improving safety performance. Through a survey for supervisors of 47 companies, Lateiner found that as a positive attitude toward safety increased the number of accidents per employee dramatically decreased. He concluded that the development of a sound safety attitude throughout an enterprise was predicated on how well supervisors met safety responsibilities. Consequently, accidents will decrease when attitudes improve as a result of supervisors effectively performing safety procedures (Mattila, 1994).

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[1]. Krause. T.R. and L.R. Russel, "The Behavior-Based Approach to Proactive Accident Investigation". Professional Safety, March 1994, P.23.

Levitt and Samelson[1] (1981) wrote in their article that:

> "in order for safety to improve, both government and contractors must take more active roles in safety management, enforcing systematic safety planning and making supervisors accountable for safety performance."

Mallett[2] (1995) stated in his article that:

> "statistics indicate that perhaps 75% of all accidents are attributable to human error. Addressing human factors within process safety analysis may uncover deficiencies in the man/machine interface. However, preventing these deficiencies in the first place will only occur when machine designers and decision makers are educated appropriately. Machine designers need to understand and apply human factors. Decision makers must understand the impact human factors have on overall business success. In addition, management should recognize that machine designers are human, their limitations must be accepted and addressed during the design for safety."

Mattila, Rentanen and Hyttinen (1994) conducted a study to determine whether there is any connection between the quality of the work environment and occupational safety. The study was conducted at

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1. Levitt, R.E. and N.M. Samelson, Improving Construction Safety Performance: The User's Role, Technical Report # 260, Standford University, 1981.

2. Mallett, Roger, "Human Factors, Why Aren't They Consider". Professional Safety, July 1995, P.31.

a construction company. Altogether 16 sites were included. The accidents were analyzed according to the company accident reports. A safety checklist was used to determine the safety level of the sites. The study proved that the quality of the work environment and the level of safety are directly connected in building construction, and the high quality work environment will improve the housekeeping and reduce the accident frequency rates.

McCook (1988) reviewed a study on three groups of Ontario construction contractors in Canada, devoting essentially the same resources to safety. One group that had made employees responsible for improved safety had "consistently poor results". A second group, which gave supervisors "the responsibility and the accountability to make an effective change in the accident rate", had better than average results. Because the supervisors were held accountable, they initiated formal inspections, training programs, accident investigations, and tool checks. The most successful group employed "management techniques of planning, directing, and controlling". The contractors in this group established quality and safety standards for their organizations, and developed safe work procedures (Grimaldi, 1989).

Shields[1] (1994) wrote in his article that:

> "effective human relations skills will help supervisors promote and improve safety by developing a climate of teamwork. Human relations skills are key in any organization because people are the ones performing the work. Safety management which effectively uses such skills to improve employee-management relations will achieve the desired safety goals."

Topf and Petrino[2] (1995) wrote in their article that:

> "the development of safe attitudes is the key to promoting safe behavior. Positive attitudes toward safety will encourage the employees to discuss safety issues and concerns without waiting for a supervisor to do so. Such proactive behavior only occurs when employees are keyed into preventive safety efforts. Without attitudinal changes and a strong sense of personal accountability, employees will not take responsibility for safety. Instead, they will revert to unsafe behavior or inaction once the observer is removed."

Turek (1991) stated in his paper the result of a study conducted in maintenance safety. The study estimated as many as 122 maintenance

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1. Shields, M.A., "Human Relations in Safety". Professional Safety, Feb. 1994, P.41.

2. Topf, M and R.A. Petrino, "Change in Attitude Fosters Responsibility for Safety". Professional Safety, Dec. 1995, P. 25.

workers in the U.S.A. die annually of work-related injuries. The study found that the main cause of death among maintenance workers was electrocution. Powerlines accounted for the highest percentage of deaths, followed by wiring and appliances. Another 28,400 lost-time injuries occur annually in maintenance. Lost-time injuries in maintenance actually increased slightly from 1975 to 1990.

2.2 SAFETY PERFORMANCE ASSESSMENT FACTORS

The assessment process of building maintenance contractors, according to a given set of safety factors, is to evaluate the safety practices and the level of compliance with safety rules and requirements in performing maintenance work .

The literature has been investigated to find out the most important factors for the safety assessment process. These main factors are as follows:

2.2.1 The Use of Safety Program or Manual

A safety program is more than a set of rules, regulations and procedures; it is a cooperative effort between employees and management. Active employee participation produces a sense of belonging. The workforce develops an internal motivation. This involvement results in higher morale and improved work performance which impacts contractor growth and success (Eckhardt, 1993).

A safety program manual mainly outlines specific essential measures that will be taken by the contractor to prevent human injuries and property damage. This manual is usually submitted by the contractor to the facility owner representative for approval. The contractor should appoint a qualified full-time safety supervisor to coordinate the program (Gallagher, 1993).

The contractor and his safety supervisor must ensure all the policies stated in his safety manual are fully implemented by the crew supervisor (Gallagher, 1993).

2.2.2 The Existence of Safety Professional / Department

Each contractor must have a safety department or he has to have at least one safety professional per shift. Detailed qualifications and experience requirements for these personnel must form a part of each contract (Gallagher 1993).

2.2.3 Safety Considerations in the Bid Process

This is perhaps the most difficult criterion to consider. Although each contractor maintains records of money spent in formal safety program in any given year, each project is organized differently. The safety cost estimator often faces difficult decisions involving allocation of safety costs for certain bidding. Two helpful tools may be used in estimating safety costs in the bidding process. These are present value calculation and annual expected value technique (Friends, 1992).

Present value calculation (PV) compares the cost of implementation against the value of the benefit:

$$PV = 1/(1+i)^n$$

where ; $i =$ discount rate or rate of return used at that year

$n =$ number of years or period of estimation

(usually a 10-year period).

The Annual Expected Value mainly represents the amount a contractor can expect to lose from injuries or losses in any one year of the contract. The higher the expected value the less the compliance to the safety rules and requirement.

Annual Expected Value

= Estimated Average Cost*(# of Losses or Injuries/# of Years)

Obviously, basing the estimate on data from a longer time period enhances the probability that the figures are representative. The way to estimate the average cost of each loss or injury incident is by reviewing records. These costs will obviously not reflect current costs. These amounts can be adjusted, however, by using an index to update them to current figures.

2.2.4 *Clear Management Safety Policy*

Unless the contractor knows why he is complying, he may not be able to identify where his compliance should begin and would not recognize the end when he came to it (Gregory, 1991). The contractor must have "total management commitment and total management involvement in safety", which is the establishment of quality and safety standards and the development of safe work procedures for his organization. Total management commitment and total management involvement in safety is the major controlling influence in obtaining success (Dial, 1992). No endeavor within an organization can function effectively without strong support from top management. For safety to be an effective program , there must be a commitment at the highest level. The commitment must include a clear statement that safety is important and support for actions that will make safety important (Brauer, 1990).

Any safety program begins with a policy insisting on the safety and protection of the employees. That policy certainly encompasses safety while at work and all matters relating to employment. For some companies, the commitment extends to off the job safety as well, like in Saudi Aramco.

Extending the program beyond the immediate boundaries of employment has several effects. First, it lets employees know that they are valued as individuals. Second, it gets employees involved in safety throughout their lives so that they do not turn safety on when they get to work and off when they leave (Brauer, 1990).

Procedures extend the policy into practice. The procedures assign responsibilities to each employee. A safety program must involve every one at every level in a contractor organization. They include general safety rules, detailed procedures and forms for particular operations, equipment and materials. The safety manual will typically address accident reporting, work permits or work orders, permits and methods and forms for dealing with hazardous materials. The detailed safety manual may include emergency responses for fire or any other conditions as well as information on worker compensation (Brauer, 1990).

Each contractor has to employ at least one safety supervisor per shift. Detailed qualifications and experience requirements for these personnel form a part of each contract. A contractor is responsible to prepare essential regulations, safety manuals and guidelines for his safety professionals to follow (Grimaldi, 1989).

2.2.5 Financial Saving As a Result of Applying Safety

A popular assumption holds that increased investment in safety produces improved safety performance. Most of the current literature suggests a relationship between safety investment and accident loss. This relationship shows that accident loss will be reduced when investment in safety is increased (Fig.2.1). Zero investment in safety usually results in maximum accident losses while initial investments have the greatest impact which result in large decreases in accident losses (Crites, 1995).

2.2.6 Accident Costs Allocation

Lost workdays, recordable injuries and accident cost losses are considered primary indicators of safety performance. A loss value is usually assigned for each fatality, for each reportable case and each lost day case, and for each serious accident. Costs attributed to expenses such as incident investigation, record-keeping and management time are added to cost losses. These figures are used to compare contractor safety performance (Crites, 1995).

2.2.7 Top Management Concern in Decreasing Frequency Rate

Management can implement several safety measures to decrease frequency rate and protect their personnel (Gregory, 1991):

1. Evaluating data regarding safety performance and the safety program periodically based on the following information (Brauer, 1990):

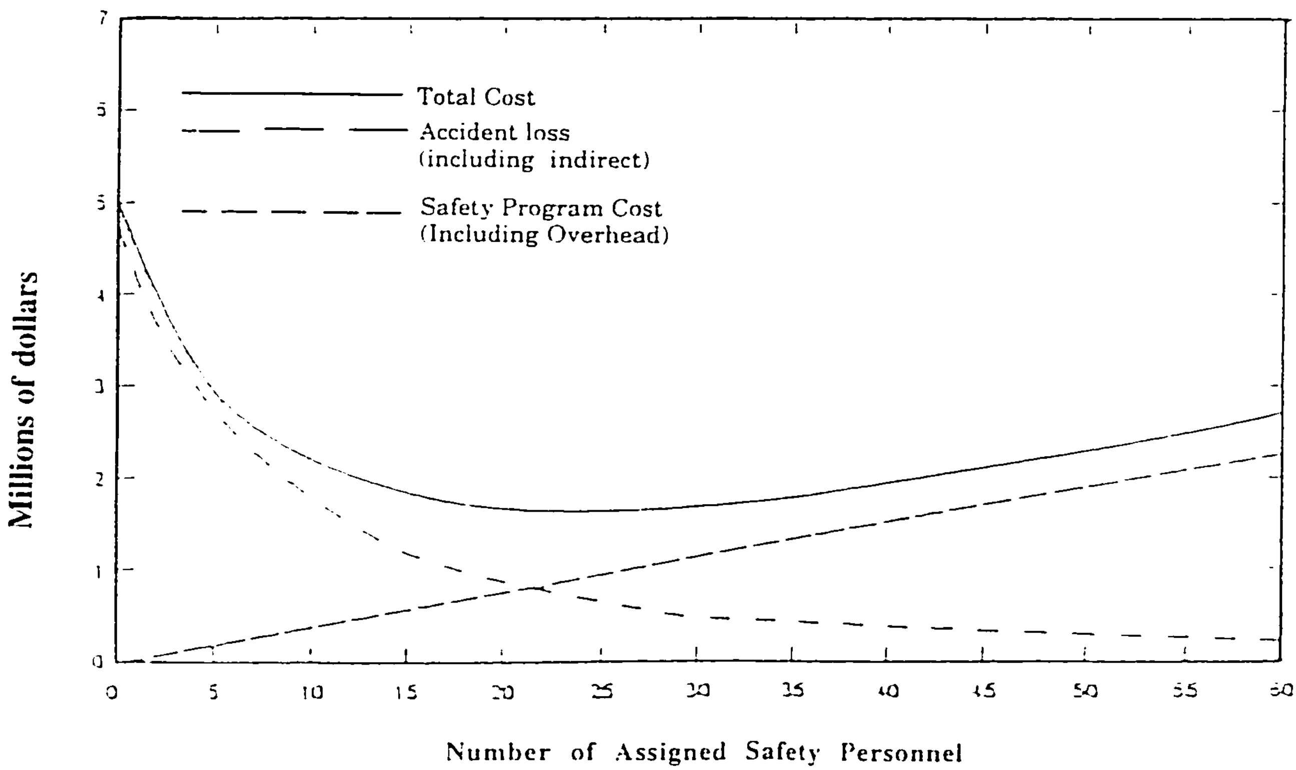


Fig. 2.1 Traditionally Accepted Safety Cost Benefit Realtionship (Crites, 1995)

a. frequency of safety meetings for safety professionals:

b. frequency of safety inspections;

. c. accident records and costs, and the frequency of reporting.

2. Analysis of accident data which can provide an indication of changes over time, and which serves as a measure of safety trends and identifying factors that influence accidents. This information can then be used to develop actions for improving safety or stop the work.

3. The use of permits for hazardous activities to ensure that communication takes place in performing work orders and that hazards are controlled. They list minimum safety precautions to be taken and hazards which must be controlled. Each permit contains a checklist of precautions against common hazards.

4. Designation of a responsible full-time safety professional for safety coordination .

5. The contractor must provide his safety professional with safety guidelines that must be followed.

6. Discussion during periodical meetings of safety matters, hazards and the procedures to be followed to prevent injury or property.

7. Establishing immediate reporting of accidents in case of all the following:

   - fatal work injuries;
   - injuries requiring medical attention which result in lost time;
   - damage to equipment or property;
   - fires.

8. Maintaining records and statistical data of accidents.

9. Conducting periodical safety inspections to detect and correct unsafe practices and conditions.

10. Conducting accident investigations.

2.2.8 Continuous Practicing of Safety by Top Management

Management's enforcement measures of safe work conditions to meet safety needs mainly means the contractor management thinks of the safety regulations as guidelines to follow to help him develop safety policies and procedures that meet specific needs. Then his whole compliance effort must be geared toward meeting these needs. Meeting the needs must become the motivation behind every written safety program, lockout/tagout system, inspection, training, and safety meeting. If safety needs are not met, accidents and injuries will occur.

Absence of accidents is concrete evidence that safety regulations are efficient and strictly complied with. Some of the safety needs which management has to meet are as follows: (Gregory, 1991):

1. **Employ Safety Professional :**

   At least one safety professional per shift is necessary to ensure enforcement of safe work conditions.

2. **Preparation of Safety Program Manual:**

   Management has to prepare essential safety regulations, manuals and guidelines for the safety supervisor or safety department to follow. The program should outline specific essential measures to be followed to prevent human injuries and property damage .

3. **Secured Power Tools and Equipment:**

   The contractor should ensure that all equipment complies with best industry standards and is maintained in a good condition. Power tools should be equipped with proper safety guards and used only in applications for which they were designed. Any tools should be free from any defect and maintained in a good operating condition.

4. **Supply of Safe Scaffolding and Ladders:**

   It is the contractor's primary responsibility to select and provide safe and suitable scaffolding and ladders for all work which cannot be done safely from ground level. The contractor is obligated to inspect and reject any defective items and to repair or replace rejected ones.

5. Provide Personal Protective Equipment:

The contractor must provide, maintain and enforce the use of personal protective equipment. The safety manual must specify the required special protective equipment to be used for each type of maintenance operation.

6. Insure Safe Transportation:

The contractor should ensure that maintenance personnel travel only in vehicles that are provided with passenger seats, seat belts, and fire fighting equipment.

2.2.9 The Use of Frequency Rates as Short Term Performance Indicator

Most of the safety literature suggests a dependency relationship between safety investment and frequency rate. These sources say management could optimize total expenditures on safety and accident rate by observing this relationship. Frequency rate was considered a primary indicator of safety performance. It is considered a better tool to assess and reflect contractor safety performance. Contractor management measures success by the presence or absence of incidents. This assumes that the presence of incidents correlates to safety problems and the absence of incidents correlates to good safety management.

The frequency rate is used to compare accident and injury statistics either within a contractor organization or within an industry.

$$\text{frequency rate} = \frac{\text{Number of Disabling Injuries} \times 1{,}000{,}000}{\text{Number of Hours Worked}}$$

(hours of exposure)

Where 1,000,000 is a scaling number used to keep the resulting value small for easy comparison.

The regular use of this formula will indicate whether or not a contractor's own accident situation is getting better safety performance.

2.2.10 The Use of Frequency Rates in Long Term Planning

Accident rate is used in planning to:

- improve existing work methods;
- change safety requirements;
- determine the causes of accidents or dangerous occurrence and recommend means of preventing recurrence;
- plan for safe standard procedures; and

- address all training deficiencies that are identified.

2.2.11 The Use of Frequency Rates in Determining Safety Objectives (Gregory, 1991):

1. assign responsibility for the efficient application of resources to achieve optimum loss control objectives;
2. establish goals for minimizing accidents and losses.
3. monitor results to ensure the effective use of manpower; materials and equipment.
4. determine the primary causes of the most serious and the most costly accidents to achieve the accident prevention objective.

2.2.12 The Use of Frequency Rates in Modifying Safety Process

One of the important uses of frequency rate and accident statistics is to discover and get feedback for areas which can then be adjusted and corrected. The corrected behavior must be reinforced in order for safety performance to improve (Gregory, 1991).

2.2.13 The Use of Frequency Rates in Preventing Future Accidents

To prevent future accident it is necessary to increase the understanding of safety processes.

The safety process consists of mainly four elements (Eckhardt, 1993):

i. The process:

Combination of people, methods, equipment, environment and procedures that work together to produce safety output.

ii. Information about safety performance:

Information about actual safety performance is gathered from process output. Evaluation of this data helps to determine whether the safety process is in a good performance condition or whether corrective action is needed.

iii. Action on the Process:

Action on the process is future oriented. It is mainly a preventive action to prevent expected accident. This action is a result of monitoring frequency rate, analyzing performance statistics and implementing appropriate actions.

iv. Action on Output Safety Process:

This step involves analyzing the gathered data and frequency rate and interpreting safety process information to detect areas where corrective action is needed to prevent future accidents.

2.2.14 The Use of Frequency Rates in Motivating the Workers

An effective safety program is more than a set of rules, regulations and procedures. It is a cooperative effort between employees and management. Active worker participation produces a sense of belonging. The workforce develops an internal motivation. This involvement results in higher morale and improved work performance which impacts contractor growth and success. Frequency rate is usually used to motivate workers' short term safety performance (Brauer, 1990):

a. Accident rate should be used in conjunction with an evaluation of people's performance or responsibilities.

b. Statistical control charts should be used for motivating and evaluating changes.

c. Accident rate should never be used to compare one person against another.

2.2.15 The Use of Frequency Rates in Measuring Safety Accomplishment

Safety accomplishment is measured by the presence or absence of accidents. This assumes that the presence of accidents correlates to safety problems and the absence of accidents correlates to good safety accomplishment and management. The most common measure of safety accomplishment used is frequency rate. Measurement frequency is usually at monthly, quarterly and annual intervals.

2.2.16 The Use of Frequency Rates in Determining Management Movement Towards the Desired Objectives

Frequency rates are usually used as qualitative indicators to evaluate changes, measure progress and warn of potential problems. For an effective evaluation of changes the contractor must determine the appropriate frequency at which rates should be calculated and rules that should be applied when determining their meaning. Statistically valid accident rates can help the contractor determine whether he is moving towards the desired objective in the long-term planning. When used as a short-term performance indicator or as a feedback mechanism it can be used for making appropriate adjustment to the safety process (Crites, 1995).

2.2.17 Conducting Safety Inspections

Good inspections are worth doing. In 1981 a survey of 143 firms in the USA showed those conducting safety inspections averaged nearly 40 percent fewer accidents than firms without an established inspection program. The mechanism of an inspection must support the program objectives, assuming these objectives are to assist contractor management in attaining the safest possible work media. Any inspection program should produce at least the following results (Gallagher, 1993):

1. Eliminate Hazards:

A good inspection program eliminates hazards by identifying their root causes and works for ultimate long-term prevention.

2. Encourage Contractor Management Commitment and Total Involvement:

Inspections are an excellent means for management to actively demonstrate their interest and involvement in the safety of company personnel and prove management commitment.

3. Provide on the Job Training for Safety Inspectors:

This training is probably most useful to the management representative. It is essential that inspectors can readily identify typical hazards present in their areas of responsibility .

4. Assess the Effectiveness of the Safety program:

The inspection is an opportunity to update management on the success, or failure of the safety program and serves as major source of management feedback. This feedback can then serve as the basis for program adjustment to correct identified weak areas.

5. Measure the Supervisor's Performance in Safety.

The inspection will let the management know how well their supervisors are doing in the prevention of safety deficiencies. The inspection must be designed to show this accountability .

2.2.18 Documentation of Unsafe Conditions

An accident is an unintended, unplanned event that is caused by unsafe acts, unsafe conditions or both and may result in immediate or delayed undesirable effects.

There are two fundamental types of accident causes: unsafe acts and unsafe conditions. Accidents involve either of these two causes or both. Losses from accidents can take many forms: besides injury and death, there are damage to property, equipment and materials and the costs associated with accidents.

Documentation of any information collected about accidents either producing injury or not can be useful in formulating the suitable preventive actions (Gregory, 1991).

2.2.19 Correction of Unsafe Conditions

Correction is started by performing safety sampling or by systematically observing employees in order to determine the unsafe acts and the defective conditions and how often they are occurring.

These results are then used to measure the effectiveness of the safety activities and to correct the defects (Gregory, 1991).

2.2.20 Continuous Practicing of Safety by Safety Professionals

1. Positive Attitude Toward Safety Supervision and Coordination:

Positive attitude toward safety supervision and coordination can be explained as how well safety professionals meet safety responsibilities. Consequently, accidents will decrease when attitudes improve as a result of safety professionals effectively performing safety supervision and coordination. An extensive study of safety supervisors from 47 companies in the USA showed that as a positive attitude toward safety increased, the number of accidents per worker dramatically decreased (Gallagher, 1993).

2. Ensuring the Availability of Protective Equipment:

Ensuring the availability of protective equipment is one of the important safety supervisor influences on safety. Examples include: safety glasses, safety shoes, and hard hats (Gallagher, 1993).

3. Maintain Property Damage and Personnel Injury Record:

Maintaining property damage and personnel injury record is to keep a record of all injuries and damages with fully detailed information. The recorded information helps later in the safety evaluation process (Dial, 1992).

4. Report Follow-up:

Report follow-up is the process of writing a report following the initial oral report of any incident detailing the circumstances, corrective action taken, and recommended action to prevent a recurrence (Gregory, 1991).

2.2.21 The Reinforcement of Safety Rules by Safety Professional

Reinforcement of safety rules involves constant follow-up to ensure compliance with safety requirements, with scheduled requirements of any priority assigned, understanding that modern management concepts of planning, organizing, training and controlling are most important to safety, and that they are necessary for positive results (Gallagher, 1993).

2.2.22 Timing Correlations of Unsafe Conditions by Safety Professional

The Safety supervisor corrects safety problems by listing prioritized safety violations to eliminate safety hazards. A separate list should be made for each foreman. The list should be sent to each foreman, and a copy to the maintenance manager or superintendent with instructions on how to eliminate the safety hazards by priority as follows (Gallagher, 1993):

1. Emergency (Priority 1):

Safety items in this category constitute an existing and immediate threat to life and should be acted upon immediately. Emergency items should be reported immediately to the manager by phone. Modification or new work required to eliminate the hazard should be covered by work orders.

2. Urgent (priority 2):

Safety items in this category constitute an imminent threat to life or limb and should be acted upon within a week. Items in this category should be approved by the manager.

3. Non-critical Safety:

Safety items in this category should be accomplished within 3 months.

In the event the maintenance manager disagreeing with a safety discrepancy, a meeting should be arranged by the manager with the safety supervisor for the purpose of resolving differences in opinion .

2.2.23 Participating of Safety Professional in Developing Safety Program

The safety manual or program includes general safety rules, detailed procedures and forms. It usually addresses accident reporting, work permits, and emergency responses. It usually identifies responsibility. Safety supervisors are normally responsible for their work areas and the workers under them. They usually manage training inspections and reporting of the problems that create hazards. The safety supervisor participates in preparing and updating safety program through the compilation by the management of the different information reported by the safety supervisor, i.e. data from accidents. Implementation includes the issue and inspection of personal protective equipment, regular testing of fire protection systems and regular schedule for training for emergency procedures (Levitt, 1981).

2.2.24 Conducting Safety Meetings

Safety meetings and safety discussion are a practice done by the safety professional, holding a ten-minute weekly meeting for the crew, discussing the hazards in the work they do and the procedures to be followed to prevent injury or property damage (Levitt, 1981).

2.2.25 Reporting of Accident to the Top Management

Learning from accident experience is one reason for compiling reports and records. Making use of those reports and information derived from records is a contractor management function. Saudi laws and regulations require record keeping and reporting. Reports and records are often needed to protect the legal rights of employers and employees. They can help identify hazards. They may be used to evaluate contractors during the selection process (Eckhardt, 1993).

Many contractors have award programs based on the number of work order hours completed without an accident. Without reports and records, these programs would be impractical. Statistics based on data compiled from reports and records can be used by contractor management to develop quantitative indicators of safety performance, decision making in safety, implementing corrective actions and safety promotions programs (Gallagher, 1993).

2.2.26 Reporting of Accidents to Social Insurance

Saudi Social Insurance requires that each contractor must keep records of job related accidents and that certain reports be submitted. If there were no records or no submitted reports of an on-the-job injury, the worker would have no way to validate his right for getting worker's compensation benefits (Gallagher, 1993).

2.2.27 Reporting of Accidents to Owner Representative

Some Saudi government organizations and private companies (i.e. Saudi Aramco) require contractors' reporting of accidents to form the basis for measuring the contractor safety performance.

2.2.28 Providing Safety Awards

Rewards for outstanding safety performance should not be different from those given for similar production or quality achievements, so after responsibilities are established and objectives are set, the only way to achieve them is to hold the person accountable. In other words, people are motivated through incentive, responsibility and respect, not by regulation to meet company goals. The use of incentive plans must avoid using competition between crews, which may pressure workers and encourage them to take unsafe short cuts (Eckhardt, 1993).

2.2.29 Availability of Hazards Recognition and Control Procedures

i. Hazards Control and Recognition:

A hazard is a condition that presents a potential for injury, death or property damage. Hazard control is any means of eliminating or reducing the risk resulting from a hazard. Hazard recognition is perceiving or being aware that a hazard exists.

Hazards may come from insufficient, delayed and improper maintenance and repair. Controlling hazards related to normal use is not sufficient. Many plans or designs fail to recognize hazards during setup. For example, in doing maintenance works, poor access to service points or the need to do servicing with high levels of energy present can be dangerous. Hazards during or resulting from maintenance must be recognized.

Failure to perform maintenance work with the proper safety procedure can introduce hazards. Errors in maintenance procedures or poorly written procedures can cause hazards. In order to minimize hazards four steps must be accomplished (Gregory, 1991):

1. recognize hazards;
2. define and select preventive actions;
3. assign responsibility for implementing preventive actions; and
4. provide a means for measuring effectiveness.

ii. Priorities in Hazard Control:

The hazard control process consists of a set of priorities. The priorities, in order of importance, are (Gregory, 1991):

a. eliminate the hazard;

b. reduce the hazard level;

c. provide safety devices;

d. provide warning devices;

e. provide safety policies and procedures; and

f. provide protective equipment.

a. Eliminate Hazard:

Hazards can be eliminated by making process or design changes or by substituting safer materials for less safe ones, for example, eliminating of manual handling steps in operation will eliminate lifting hazards. A non-combustible material can replace a combustible one. Sharp corners can be rounded.

b. Reduce hazards:

If the hazards cannot be removed, the degree of hazard can often be reduced by reducing the degree of severity or reducing the probability of occurrence. For example, placing a fire hazard where there are few people reduces hazard severity. Using smaller quantities of flammable material or reducing energy levels at an occupied location is also a severity reduction. A sprinkler system does not prevent fires but minimizes their severity.

c. Safety Devices:

Safety devices are automatic devices or controls that prevent workers from being exposed to a hazard. Devices such as machine guards, interlocks, lockouts, automatic fire doors, and electrical circuit breakers or fuses are all forms of safety devices.

d. Warning Devices:

Warning devices or signals often rely on the visual or auditory senses of people. Some examples are signs, alarms, flags, labels, flashing or changing lights and horns and any other means that can be used to notify workers that a hazard exists. Warning devices are mainly a function of effective communication and workers' training or background.

e. Safety Policies and Procedures:

Polices are safety statements of goals, objective, and operational principles that govern a contractor organization and are supported and approved by the contractor management. Procedures are detailed implementation instructions for policies or sets of actions that must be executed. Procedures give step-by-step information about what to do in particular situations. They are the lowest control on the priority list because they depend totally on human behavior to recognize the hazard and take appropriate corrective action. Procedures extend the policy into practice and assign responsibilities. In maintenance there are two types of procedures: routine activities standard operating procedures, and non routine activities emergency operating procedures that are developed by job safety analysis process.

e. Personal Protective Equipment:

Personal protective equipment usually is an element of a procedure.

iii. Job Safety Analysis:

A technique is needed to help identify what behaviors are safe and correct. It is done by identifying the hazards associated with maintenance activities and practices, and how to do the job correctly and safely. The hazard analysis and recommended practices and procedure can become part of a user safety manual, operations manual or training program.

iv. Safety Manual or Program:

A safety manual includes general safety rules, detailed procedures and forms. It usually addresses accident reporting and work permits. The detailed safety manual may extend to particular practices and include emergency responses to hazardous operations and use of certain equipment and tools.

a. Assigning Responsibility:

A safety program usually identifies responsibility. For example, supervisors are normally responsible for their work areas and the workers under them. They usually manage training, inspections and reporting of the problems that create hazards. They may have safety included in their job description and safety performance may be part of their performance standard.

b. Implementation of Safety Program:

Implementation of safety involves getting schedules for inspection and safety meetings. It includes compiling information from forms and procedures, i.e. data from accidents. Implementation includes the issue and inspection of personal protective equipment, regular testing of fire protection systems, and regular schedule for training for emergency procedure.

c. Training:

Workers must learn about the hazards related to their job and how to perform particular safety procedures, how to use personal protective equipment, and how to respond to emergencies.

d. Risk Identification:

The goal in risk identification is to reduce uncertainty and to describe factors that contribute to accidents and injuries. It involves identification of hazards. Frequency and severity data from accidents, and review of accident records can identify risks. Various statistical methods applied to accident data introduce factors contributing to accidents and injuries.

v. Colors and Signs in Safety:

Color is useful in safety for marking hazards and coding information. Signs take many forms, i.e. tags for lockout and tagout procedures. They mark hazards at a particular location during maintenance work and provide warnings. They need to incorporate standard color codes where applicable. Signs should be multilingual and include symbols.

2.2.30 Performing Periodic Hazard Review

A. Factor Consideration in Hazard Reviews (Gregory, 1993):

1. Access and Circulation:

   Emergency equipment personnel should have easy access to all locations. Circulation areas should be clearly marked in the work plan prior to initiating the work order.

2. Materials used should meet fire protection requirements.

3. Work surfaces should be slip-resistant

4. Consideration of routine and emergency communications.

5. Analyze the fire loads, fire controls, and water supplies where extinguishing water is needed.

6. Safety considerations for equipment such as guarding, noise control, and electrical grounding.

B. Type of Hazards and Control (Saudi Aramco Loss Prevention, 1985):

1. Ladder Hazard:

Ladder steps must have surface resistance to prevent slips and falls. Steps must have side protection. Proper positioning will prevent ladders from tripping or sliding. In case of metal ladders they should not be used around electrical connections or equipment. Ladders should be inspected regularly and defective ones removed.

2. Scaffold Hazards:

A major hazard for scaffolding is overloading. Scaffolds should be inspected before use. Complete assembly of all fastening bolts, connectors and bracing is important. Ropes, clamp tightness, and out-rigger beam should all be checked. Scaffold should be prevented from tipping by tying it to an adjacent wall of the building.

3. Electrical Hazards:

Electricity and electrical equipment create or contribute to a number of direct and indirect hazards. The most common direct ones are electric shock, heat and fire. There are many kinds of indirect hazards that electrical and electronic equipment create or contribute to, for example, when electricity energizes equipment, mechanical hazards may result. There are a variety of controls that can reduce or eliminate electrical hazards. There are controls such as using non-conductive materials to cover most electrical wires, rubber pad isolation, over-current devices like fuses and circuit breakers, switching devices like lockouts, interlocks which are usually attached to access doors and gates which shut off the power to equipment when a door or gate opens, and grounding which removes charge from bodies and protects workers from electrical shock.

4. Tool and Machine Hazards:

Tools and machines are a major source of injuries. They cause about 8% of lost time accidents. One hazard is being struck by a tool, moving machine, machine part or flying materials. Another kind of hazard is getting caught in a machine or tool. Guards on machines are also important safeguards or barriers. Switches and interlock can also be used to control or shut off the machine or equipment in case of hazard.

5. Welding and Cutting Hazards:

One maintenance process is welding and cutting. Unsafe welding and cutting procedures too often lead to fires. They can also damage eyes. The main types of welding are electric welding and oxygen welding. Welding equipment needs special care to ensure that it is not accidentally operated. Oxygen must he handled carefully and maintained properly. The environments for welding and cutting must be free of flammable gases. Welders must have training and they should wear proper protective clothing.

6. Storage Hazards:

Flammable liquids are used in many maintenance operations for cleaning, for fuel and other purposes. To prevent fires they must be stored in safe cans away from heat.

7. Compressed Fluid and Gas Hazards:

Pressurized gases and fluids can cause injury. One control for the hazard of compressed air is reducing the pressure to a low level. Hoses should have extra protection with the use of guarding.

8. Heat Hazards:

The effects of high temperature can be grouped into excessive exposure to heat and burns. Excessive exposure to a hot environment can cause failure of the temperature regulatory mechanism of the body. Burns result from contact with hot materials or surfaces. Heat exposure and thermal injuries can be reduced or eliminated by:

a. applying insulation to heat sources;

b. modifying the environment of work by ventilation, i.e. air conditioning;

c. adjusting the work by limiting the time of exposure to hot sources and providing the necessary tools and equipment to reduce the work effort required;

d. providing protective clothing.

9. Cold Hazards:

Cold can produce local tissue damage and reduce the temperature of the body. Controls for preventing injury from cold temperature include:

a. modifying the environment of work by warming the air temperature;

b. minimizing duration of exposure by adjusting activities;

c. providing protective clothing to retain body heat.

10. Noise Hazards:

There are many effects of noise on workers. The major ones are:

a. long exposure to noise producing hearing loss;

b. Noise interfering with communication in a noisy work place.

One way to control noise problems is to analyze processes and equipment during planning in order to prevent noise problems from occurring by replacing or modifying noise sources.

11. Vibration Hazards:

Operating vibrated equipment may cause more back troubles than other kinds of maintenance jobs. The best control for vibration problems is to prevent vibration from being applied to the body.

12. Confined Space Hazards:

The main hazard of confined spaces (i.e. underground utility) is oxygen deficiency. Prior to entry, ventilation systems must be set up to produce adequate air supply.

13. Chemical Hazards:

The main hazards for chemicals are effect on health and fires. Exposure to chemicals can be avoided by:

a. substitution of non-hazardous substances;

b. enclosing a source;

c. using protective clothing;

d. ventilation.

14. Working Surface Hazards:

A working surface is the surface on which workers stand, work, walk and climb. They contribute to many accidents, injuries and death. A study of California worker compensation claims found that

21% of job-related serious injuries are caused by work surfaces. Tripping or slipping, which are caused by irregular or slippery work surfaces, can be controlled by good housekeeping. Working surfaces must be kept clean and free of foreign materials such as liquids, tools, scrap and waste. Another control is by using rough safety shoes.

15. Fall Hazards:

Falls often cause injury. They may result from slipping, tripping, falling from one surface to another, and from falling objects. Falls can be prevented by:

a. Removing slipping and tripping hazards;

b. The use of warnings and barriers particularly where there are changes in level between surfaces.

2.2.31 Providing Orientation Program for New Employees

2.2.32 Instructions on Personal Protective Equipment (Saudi Aramco Loss Prevention, 1985):

A. Ensuring Adequacy

Personal protective equipment is essential protection for many hazards. There are several things that may prevent it from being adequate (19):

1.Effectiveness:

Having the right equipment for the hazard.

2. Fit:

It must fit the user. Poor fit may result in inadequate protection.

3. Use:

Workers must wear personal protective equipment, even though the hazard it protects against is not present at all times.

B. Ensuring Performance:

1.Inspection and Testing:

Regular periodic inspection and testing for condition and function help ensure performance.

2. Maintenance:

Personal protective equipment that is not in good condition or not properly adjusted for fit needs corrective action.

3. Replacement:

Equipment that is not in good condition and not repairable must be removed from use and replaced by a new one.

C. Ensuring Protection:

1.Head Protection:

One danger to the head is falling or flying objects. Helmets or hard hats are the type of equipment which is used for head protection.

2. Eye and Face:

Flying objects and particles, dust, chemical liquids, excessive light and radiation, may injure the eye or face. Safety lenses, eye glasses, and goggles can be used to prevent injuries and provide adequate protection.

3. Hearing Protection:

Exposure to excessive noise will produce temporary or permanent hearing loss. There are two kinds of hearing protection devices: muffs, which fit over the ears to keep sound from entering the ears, and plugs which are inserted into the ear canal.

4. Respiratory Protection:

Excessive concentrations of certain gases and particles can interfere with breathing and create a health hazard if inhaled. The use of a mask or air filter can prevent inhalation of such gases through the nose or mouth.

5. Hand, Finger and Arm Protection:

There are many hazards for hands, fingers and arms. One hazard is hot or cold materials. Another hazard is sharp objects and equipment. Chemicals are another hazard. Gloves, mittens and sleeves provide the necessary protection for hands and fingers.

6. Foot and Leg Protection:

A major hazard for the foot and leg are falling, slipping and stepping on nails. Standard safety shoes can prevent many injuries. Fall protection systems such as safety belt, safety nets or catch platforms should be used.

7. Electrical and Heat Protection:

Workers who work around electrical equipment or heat sources face the danger of current flowing through them or high heat. Their personal protection must include electrical and heat insulating properties.

2.2.33 Providing Instructions on Safe Work Practices

A. Performance of Maintenance Workers Practices:

I. Motivation:

The following are some motivation tools to measure safety performance (Gregory, 1991):

1. accident frequency as short - term safety performance;

2. checks on activities: i.e. safety meetings, performing safety inspection;

3. safety sampling: by systematically observing employees in order to determine the unsafe acts being committed and how often they are occurring. These results are then used to measure the effectiveness of safety activities;

4. safety activities auditing by outside auditors. Audits provide an opportunity for positive reinforcement of good performance and corrective feedback on poor performance;

5. provide reward or corrective action according to performance.

II. Judgment and Attitude:

The action taken as a result of a judgment is a more desirable action when there is a good background of safety knowledge, experience and training. Attitudes may be related to behavior. Attitudes may be positive or negative action.

III. Emotions:

Emotions are mainly feeling expressions. Emotions may be generated by situations at home or at work and they may be associated with other people, with activities or conditions. Control of emotions is mainly by controlling the situations that generate them.

B. Workers Practices and Safety (Levitt, 1981):

I. Training:

Training provides the knowledge and skill workers require to act safely. Knowing the appropriate action and performing it correctly requires training and practice.

II. Enforcement:

Enforcement involves formalized safety rules and procedures and following them. Enforcement involves someone else auditing the actions of others. With enforcement there may be some consequences for not acting properly or for unsatisfactory performance of tasks.

III. Communication:

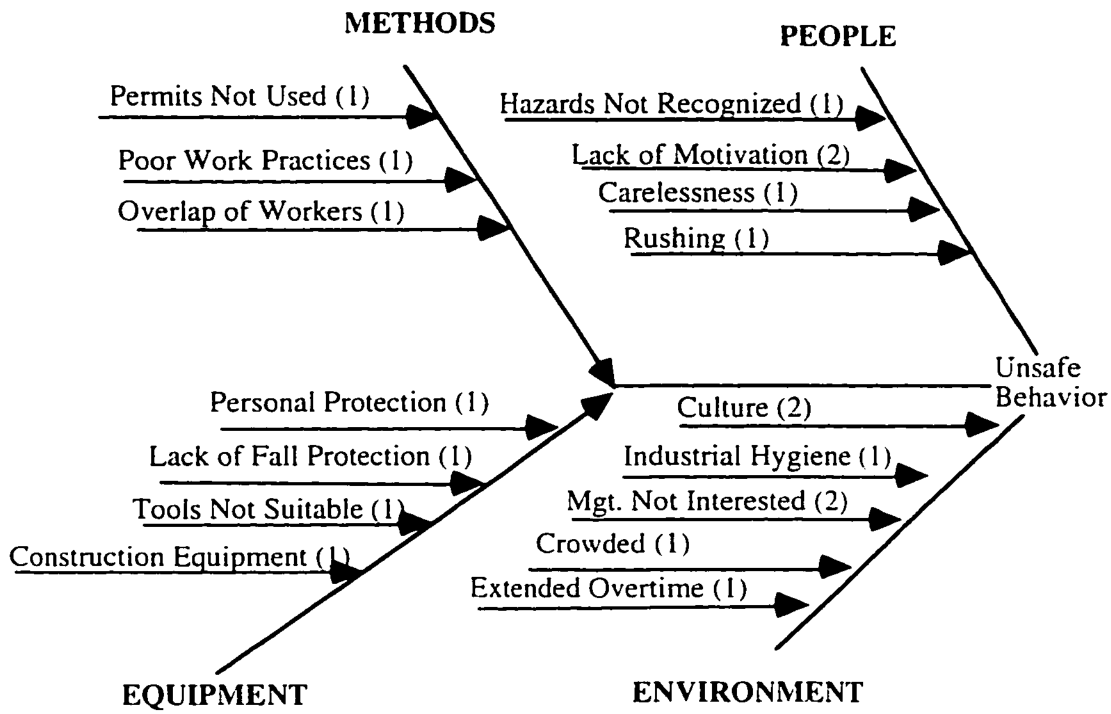
Communication usually involves safety training, safety supervisor instructions and comments, published procedures, rules, warnings, and instructions. Workers cannot be expected to decide and act on their own if they do not have the knowledge, skills and experience to recognize a dangerous condition and know what actions are appropriate.

IV. Feedback:

Correct practice must be reinforced and performance is greatly enhanced by knowledge of results. If any worker does his work correctly or incorrectly, he needs to know. Safe practice requires feedback on performance. Feedback may be verbal or in the form of reports of measured results of actions. Immediate feedback is generally better than delayed feedback.

C. The Use of Worker's Safety Practice Factors as Predictors of Worker's Safety Performance.

The use of worker's safety practice factors as predictors of worker's safety performance is mainly to determine the worker's safety behavior by the combined influence and interaction of these factors (Fig.2.2). Worker's safety practice factors were studied in relation to individual and situation factors (Fig.2.3). In this regard, studies showed that worker's safety practice factors and performance depend mainly on the following conditions (Nicole, 1988):



Notes:

(1). Measurement by observation (No. of violations / No. of workers observed)

(2). Measurement by survey

Fig. 2.2 Causes of Unsafe Behavior Results from the Combined Influence and Interaction of Worker's Safety Practice Factors.(Nicole, 1988).

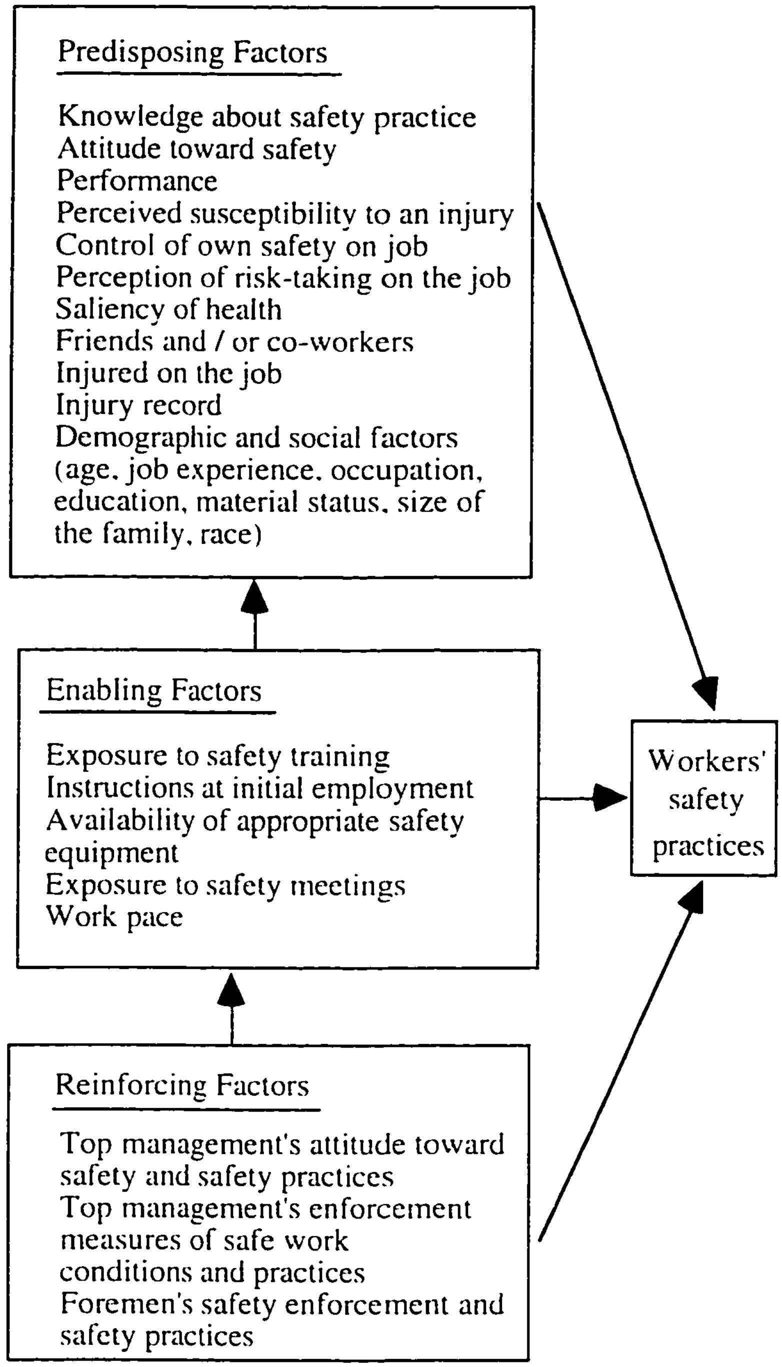


Fig. 2.3: Worker's Safety Practice Factors (Nicole. 1988).

1. predisposing factors that provide the rationale or motivation for the behavior, such as: age, knowledge about safety practices, and attitude toward safety performance;

2. enabling factors that allow aspirations to be realized, such as: exposure to safety training, regular safety meetings, and availability of safe equipment.

3. reinforcing factors that provide continuing reward, incentive or disincentive for behavior, such as: management's attitude toward safety practices, management's attitude toward worker safety, and foreman's safety enforcement;

The basic assumption is that workers who show a high compliance with safety rules are the most powerful predictors of contractor safety performance.

2.2.34 Providing Instructions on Emergency Procedures

I. Priorities in Emergency Procedures (Saudi Araamco Loss Prevention, 1982).

1. safety of workers and residences;

2. protection of property. The proper actions depend on the kind of emergency and the kind of facility, process or location;

3. removal or cleaning up of hazardous materials to make an area safe;

4. restoring operations and getting things back to normal.

II. Emergency Planning:

A key to a successful emergency is planning. Planning should include (Grimaldi, 1989):

1. the first component of an emergency plan is what actions should be taken in different situations;

2. for each action there should be participants to perform them;

3. participation must have authority when an emergency occurs;

4. communication is one of the most critical components in an emergency procedure because information flow is essential and decisions must be made quickly;

5. during an emergency there is a need for key data about the site, utilities evacuation routes, location of resources, maps, data bases, phone directory and other information sources;

6. emergency supplies such as medical and first aid supplies and equipment such as fire extinguishers, and cranes must

be available when an emergency occurs. Emergency procedures need to identify what supplies and equipment are needed in what quantities and at what locations;

7. emergency planning needs to include training requirements for participants and make them knowledgeable about the hazards;

8. in the design of buildings or facilities a backup power supply should be in place, and emergency lighting should be available if needed.

III. Posting of Safety Instructions and Emergency Procedures:

Posting of safety instructions and emergency procedures is a communication method to announce the following (Grimaldi, 1989):

- All required safety rules and emergency procedures;
- Warning signs to ensure protection of general public;
- A list of emergency telephone numbers and information regarding doctors, hospitals, ambulance services, police and fire department.

2.2.35 Providing Instructions on First Aid Procedures

Provision of First-Aid supplies, and training is the immediate help that is provided by the contractor through the maintaining of adequate First-Aid supplies for his employees, and he should request all the supervisors and foremen to attend an approved First-Aid course. The contractor should post a clear First-Aid procedure which indicates the following (Grimaldi, 1989):

1. person who is in charge of first-aid facilities or first-aid supplies;
2. the hospital to which any injured person who requires hospital treatment is to be sent;
3. the emergency telephone number to be called for assistance.

2.2.36 Providing Instructions on Accident Investigation

Investigating contractor accidents is the process of conducting accident investigation in a manner which will provide facts rather than faults. The point of such an investigation is to prevent recurrence of similar accidents. All supervisors should be trained to recognize a serious accident and take the proper steps to prepare for or conduct an investigation. They should have a general idea of the need for accident investigation and its basic principles and components. The main steps in accident investigation include (Longford, 1984):

1. the safety supervisor must take immediate action over the accident and ensure that the injured people are cared for.

2. the accident location should be roped off and protected so that no one makes changes. If it is necessary to make some changes such as stopping leakage, careful notes and/or photographs should be taken;

3. the witnesses should be interviewed and asked about what they know. This interview should be recorded;

4. after the interview, it is important to take photographs;

5. accurate measurements should be taken in the accident location, including drawing of the location of the injured, witness, machinery and any other items. This type of drawing, along with photos should give a clear accurate picture of the accident scene.

2.2.37 Providing Instructions on Fire Protection and Prevention

Life Safety Codes in Building Maintenance:

Life safety codes deal mainly with providing workers and occupants with (Saudi Aramco Loss Prevention, 1985):

a. a reasonable degree of safety from fire in a facility, and;

b. an adequate opportunity to exit facilities if a fire occurs.

1. Workers' Behavior in Fires:

Under the stress of a fire situation, workers don't always behave logically. The behavior of one person may affect the behavior of others and the ability to perform correctly during a fire depends on how workers are exposed to training in such conditions.

2. General Principles of Life Safety:

Provision of life safety codes addresses many properties such as number of locations of exits, alarm systems and extinguishing systems.

3. Fire Extinguishment:

Fire extinguishment is the application or the use of agents to control fire spread. The most common agents are water, foams, and dry chemicals. There are many kind of extinguishers, the most common ones are portable extinguisher and water extinguisher. Contractor personnel should be aware of the fire fighting equipment that is available and familiar with how to use it. Each contractor must provide or request and maintain adequate fire extinguishers readily available in each maintained building.

4. Fire Codes and Standard:

There are many building codes in Saudi Arabia that incorporate many design requirements to minimize the chances of fire in a building, minimize the rate at which fires spread and to ensure exiting by occupants. National defense is the primary source of standards in the Kingdom of Saudi Arabia regarding matters associated with fire.

5. Fire Safety in Buildings:

The main objectives for fire safety during building maintenance are:

a. getting occupants out safely;

b. minimizing property loss for structures and contents, and

c. minimizing interruption of operations and utilization: through proper design of facilities, fires can be confined to the floor and even to the room of origin.

6. Control of Ignition and Burning Sources:

a. electrical equipment should be checked regularly for defects;

b. smoking is permitted only in designated areas;

c. welding equipment, heating appliances, and any hot surfaces should be kept or used away from combustible materials.

d. all flammable liquids must always be stored and transported in securely capped containers.

e. waste materials should be removed at regular intervals and always at the end of the working day. Good housekeeping can eliminate many of the situations where a fire can start.

f. every fire should be reported. The contractor must ensure that the emergency telephone number is readily available at all telephones and that signs are appropriately placed indicating how to report the emergency correctly.

2.2.38 Providing Safety Training

1. Existence of Safety Training Program:

The existence of a safety training program is important for safe working practice. It is mainly the integration of safe working practice by teaching workers the facts about accident causes and indicating the preventive measures to be taken. Equally important, however, is the requirement of further training programs for the skilled supervisor or worker, whose techniques may need bringing up-to-date and into whose earlier training accident prevention may not have been integrated to the extent now realized to be essential (Petersen, 1984):

2. **Exposure to Safety Training:**

Exposure to safety training is the development of a safety training program for all employees potentially exposed to safety during hazardous maintenance operations, and they must receive training on how to respond to expected emergencies. Maintenance employees must not perform any operation unless trained to the level required by their job function and responsibility. They must also be certified by a qualified instructor as having completed training (Grimaldi, 1989):

3. **Alert Workers and Teach Skills and Knowledge of Safety Practices:**

Training alerts workers to potential hazards they may encounter, and teaches knowledge and skills needed to perform work with minimal risk (Nicole, 1988).

4. **Conducting a Safety Orientation Program:**

Conducting a safety orientation program is the initial step towards safety training. It is needed for new employees who are likely to be exposed to risk before their job training is complete. It should familiarize new employees with common types of hazards and the precautions that they are expected to take. It should also cover the broad requirements of the contractor's own accident prevention policy, e.g. if it is company policy that safety helmets and protective footwear should always be worn, then this should be made clear and they should be told how and where to obtain them (Grimaldi, 1989).

5. **The Use of Persuasion:**

The training providing safety skill and information should be supplemented by the techniques of persuasion. Persuasion has an important function. Its most common form is the poster used to indicate bad habits, pin-point the advantages of safe working, or give detailed information, advice, or instruction on special points (Saudi Aramco Loss Prevention, 1985).

2.2.39 Conducting Safety Meetings for Safety Professionals

Safety meetings involve safety professionals holding a ten-minute weekly meeting, discussing the hazards in the work they do and the safety procedures to be followed to prevent injury or property damage (Petersen, 1984).

2.2.40 Performing Foreman Safety Training

Foremen must be trained to protect their crew from injury or death which may cause:

a. production loss;

b. low morale;

c. low labor productivity, and

d. labor relation problems.

They should be trained to work with the safety supervisor in eliminating safety hazards, to discuss safety when briefing the men on jobs, and alert them to the unusual hazards of a particular job and what is required of them to conduct the work safely (Saudi Aramco Loss Prevention, 1985).

2.2.41 Performing Accident Analysis and Investigation

Another form of accident analysis is accident investigation. The primary purpose it to prevent future accidents. Another purpose is to identify causes of accident and injuries. A third purpose is to compile legal evidence to be used in the event of claims for losses or injuries (1). Accident investigation may help asses the degree of damage and the value of losses.

Analyzing accident investigation data is a critical part of the investigation process. Analysis of accident investigation data can provide an indication of contractor safety trends. The analysis leads to findings and conclusions. Written reports should include procedures, results of analysis, findings, conclusions and recommendations to prevent such incidents in the future (Longford, 1984).

2.2.42 Applying Previous Accident Investigation Findings in Preventing Future Accidents

It is not sufficient to end an investigation with a report. The recommendations provided in an investigation report should lead to engineering changes, procedural changes, changes in policy, rules or regulations, improved training and other kinds of actions (Brauer, 1990).

CHAPTER 3

RESEARCH METHODOLOGY AND SURVEY DESCRIPTION

3.0 INTRODUCTION

This chapter discusses the research methodology and methods in forming the questionnaire which has been used in this study. The formulated questionnaire was formed and designed by using the following resources:

- preliminary interviews with the Saudi Aramco Loss Prevention Department;

- interviews with some of Saudi Aramco's maintenance contractors.

- previous studies, which were discussed in Chapter 2, section 2.1 of this thesis.

3.1 RESEARCH METHODOLOGY

Measuring the safety performance level in performing building maintenance works was done through gathering data using the developed questionnaire.

In this study, the questionnaire was distributed by mail to a random selection of maintenance contractors and it was restricted to the Eastern

Province of Saudi Arabia. The total number of building maintenance contractors in the Eastern Province is 430.

Frequency rates and safety attitudes were used to assess maintenance contractors' safety performance level.

Microsoft Excel Power Point was used to calculate, statistically analyze and display the results on tables and on different graphical distribution formats.

A flow diagram of the research methodology utilized in the study is presented in Figure 3.1

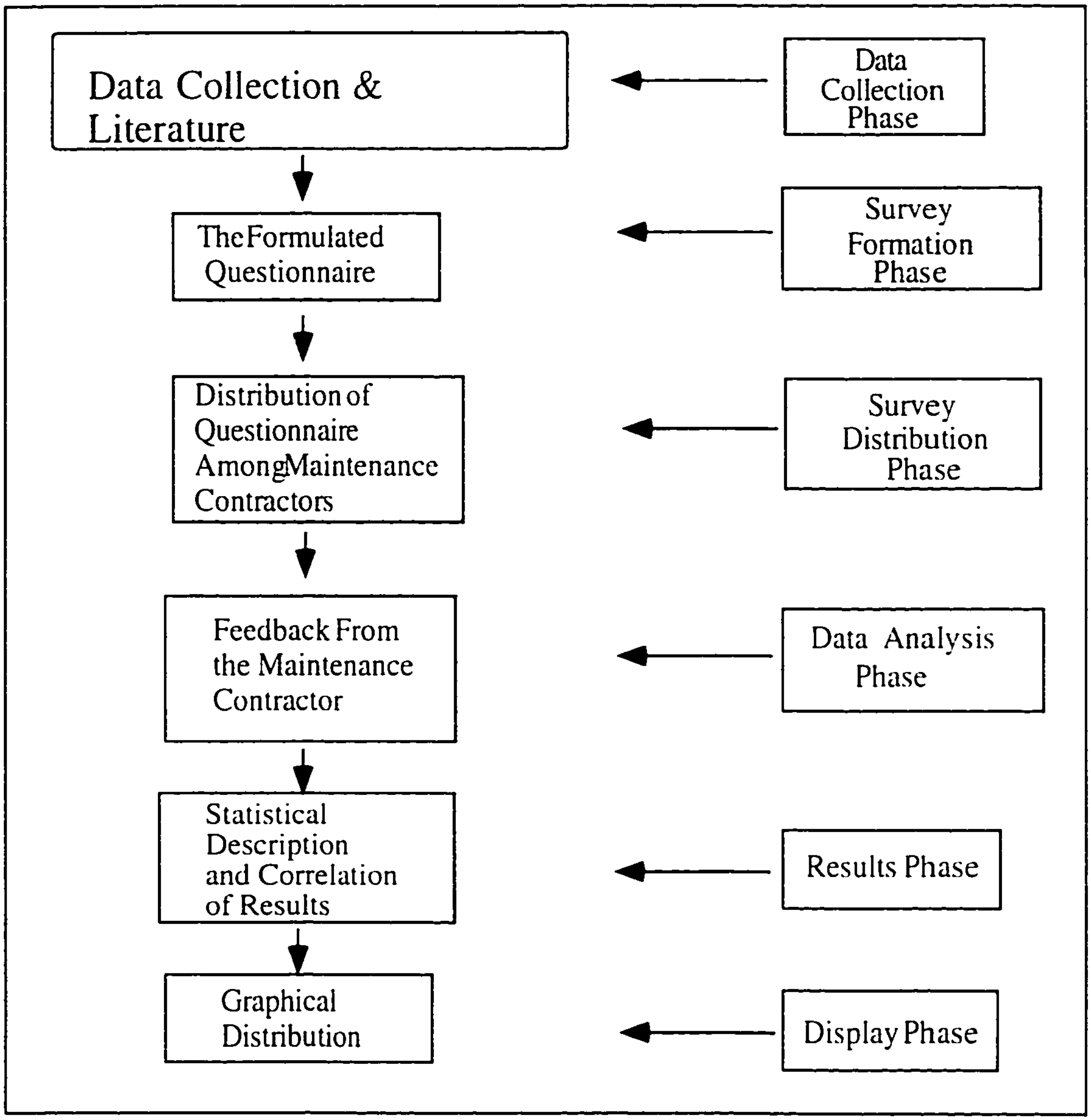


Fig. 3.1: Research Methodology

3.2 QUESTIONNAIRE DESCRIPTION

The questionnaire used in this study, shown in Appendix B, consists of two parts. The first part of the questionnaire contains general information and this includes the total number of disabling injuries / year (Lost Work Day Injury), and the total workorders hours/year. The second part of the questionnaire contains 42 safety factors relevant to contractor safety. These factors are listed in Table 3.1.

The safety factors were used to measure the contractors' safety attitudes. The safety factors were presented so that the maintenance contractor could respond to what extent each safety factor impacts his safety performance on a scale from 0 to 4; 0 (Never, No) and 4 (Always, yes).

Table 3.1: Safety Level Assessment Factors Used in the Questionnaire

No.	Safety Factors
1.	The Use of Safety Program or Manual
2.	The Existence of Safety Professional/Department
3.	Safety Consideration in the Bid Process
4.	Clear Management Safety Policy
5.	Financial Saving as a Result of Applying Safety
6.	Accident Costs Allocation
7.	Top Management Concern in Decreasing Frequency Rate
8.	Continuous Practicing of Safety by Top Management
9.	The Use of Frequency Rates as Short Term Performance Indicators
10.	The Use of Frequency Rates in Long Term Planning
11.	The Use of Frequency Rates in Determining Safety Objectives
12.	The Use of Frequency Rates in Modifying Safety Processes
13.	The Use of Frequency Rates in Preventing Future Accidents
14.	The Use of Frequency Rates in Motivating the Workers
15.	The Use of Frequency Rates in Measuring Safety Accomplishment
16.	The Use of Frequency Rates in Determining Management Movement Towards the Desired Objective
17.	Conducting Safety Inspections
18.	Documentation of Unsafe Conditions
19.	Correction of Unsafe Conditions
20.	Continuous Practicing of Safety by Safety Professionals
21.	The Reinforcement of Safety Rules by Safety Professionals

Continued Table 3.1

No.	Safety Factors
22.	Timing Corrections of Unsafe Conditions by Safety Professionals
23.	Participation of Safety Professionals in Developing Safety Programs
24.	Conducting Safety Meetings
25.	Reporting of Accidents to the Top Management
26.	Reporting of Accidents to Social Insurance
27.	Reporting of Accidents to Owner Representative
28.	Providing Safety Awards
29.	Availability of Hazard Recognition and Control Procedures
30.	Performing Periodic Hazard Reviews
31.	Providing Orientation Program for New Employees
32.	Providing Instructions on Personal Protective Equipment
33.	Providing Instructions on Safe Work Practices
34.	Providing Instructions on Emergency Procedures
35.	Providing Instructions on First Aid Procedures
36.	Providing Instructions on Accident Investigation
37.	Providing Instructions on Fire Protection and Prevention
38.	Providing Safety Training
39.	Conducting Safety Meetings for Safety Professionals
40.	Performing Foreman Safety Training
41.	Performing Accident Analysis and Investigation
42.	Applying Previous Accident Investigation Findings in Preventing Future Accidents

3.3 SCORING

For the first part of the questionnaire, no scoring was used. For the second part the safety factors were ranked and a calculated safety attitude score value was given to each contractor. The respondents had the following options for each question.

- Always, yes (4 points)
- Most of the time (3 points)
- Sometimes (2 points)
- Rarely (1 point)
- Never, No (0 point)

Figure 3.2 shows the evaluation and scoring procedure of safety factors.

The average value and the importance-index of each safety factor are calculated as shown in Table 3.2. The safety factors were ranked according to their importance index.

SAFETY LEVEL IN PERFORMING BUILDING MAINTENANCE WORK SURVEY EVALUATION

LEGEND **Yes = 4** **No = 0**

Always = 4, Most of the Time = 3, Sometimes = 2, Rarely = 1 Never =0

	SAFETY CRITERIA	EVALUATION				
		0	1	2	3	4
1	The Use of Safety Program or Manual	☐	☐	☐	☐	☐
2	The Existence of Safety Professional / Department	☐	☐	☐	☐	☐
3	Safety Consideration in the Bid Process	☐	☐	☐	☐	☐
4	Clear Management Safety Policy	☐	☐	☐	☐	☐
5	Financial Saving as a Result of Applying Safety	☐	☐	☐	☐	☐
6	Accident Costs Allocation	☐	☐	☐	☐	☐
7	Top Management Concern in Decreasing Frequency Rate	☐	☐	☐	☐	☐
8	Continuous practicing of Safety by Top Management	☐	☐	☐	☐	☐
9	The Use of Frequency Rates as Short Term Performance Indicators	☐	☐	☐	☐	☐
10	The Use of Frequency Rates in Long Term Planning	☐	☐	☐	☐	☐
11	The Use of Frequency Rates in Determining Safety Objectives	☐	☐	☐	☐	☐

Fig. 3.2: Evaluation and Scoring Procedure of Safety Factors

Continued Fig. 3.2

SAFETY CRITERIA	EVALUATION 0	1	2	3	4
12 The Use of Frequency Rates in Modifying Safety Processes	☐	☐	☐	☐	☐
13 The Use of Frequency Rates in Preventing Future Accidents	☐	☐	☐	☐	☐
14 The Use of Frequency Rates in Motivating the Workers	☐	☐	☐	☐	☐
15 The Use of Frequency Rates in Measuring Safety Accomplishment	☐	☐	☐	☐	☐
16 The Use of Frequency Rates in Determining Management Movement Towards the Desired Objective	☐	☐	☐	☐	☐
17 Conducting Safety Inspections	☐	☐	☐	☐	☐
18 Documentation of Unsafe Conditions	☐	☐	☐	☐	☐
19 Correction of Unsafe Conditions	☐	☐	☐	☐	☐
20 Practicing of Safety by Safety Professionals	☐	☐	☐	☐	☐
21 The Reinforcement of Safety Rules by Safety Professionals	☐	☐	☐	☐	☐
22 Timing Corrections of Unsafe Conditions by Safety Professionals	☐	☐	☐	☐	☐

Continued Fig. 3.2

SAFETY CRITERIA	EVALUATION 0	1	2	3	4
23 Participation of Safety Professional in Developing Safety Programs	☐	☐	☐	☐	☐
24 Conducting Safety Meetings	☐	☐	☐	☐	☐
25 Reporting of Accidents to the Top Management	☐	☐	☐	☐	☐
26 Reporting of Accidents to Social Insurance	☐	☐	☐	☐	☐
27 Reporting of Accidents to Owner Representative	☐	☐	☐	☐	☐
28 Providing Safety Awards	☐	☐	☐	☐	☐
29 Availability of Hazards Recognition and Control Procedures	☐	☐	☐	☐	☐
30 Performing Periodic Hazard Reviews	☐	☐	☐	☐	☐
31 Providing Orientation Program for New Employee	☐	☐	☐	☐	☐
32 Providing Instructions on Personal Protective Equipment	☐	☐	☐	☐	☐
33 Providing Instructions on Safe Work Practices	☐	☐	☐	☐	☐
34 Providing Instructions on Emergency Procedures	☐	☐	☐	☐	☐
35 Providing Instructions on Fire Aid Procedures	☐	☐	☐	☐	☐

Continued Fig. 3.2

SAFETY CRITERIA	EVALUATION 0	1	2	3	4
36 Providing Instructions on Accident Investigation	☐	☐	☐	☐	☐
37 Providing Instructions on Fire Protection and Prevention	☐	☐	☐	☐	☐
38 Providing Safety Training	☐	☐	☐	☐	☐
39 Conducting Safety Meetings for Safety Professionals	☐	☐	☐	☐	☐
40 Performing Foreman Safety Training	☐	☐	☐	☐	☐
41 Performing Accident Analysis and Investigation	☐	☐	☐	☐	☐
42 Applying Previous Accident Investigation Findings in Preventing Future Accidents	☐	☐	☐	☐	☐

Contractor Safety Attitude Score	----------------------

Table 3.2: Method of calculating the Average Values and Importance Index

No.	Safety Factor	4 Always, Yes	3 Most of the time	2 Sometimes	1 Rarely	0 Never, No
		No. of Participants Marked				
17	Conducting Safety Inspection	17	6	3	1	0

$$\text{Average Value} = \frac{(17x4)+(6x3)+(3x2)+(1x1)+(0x0)}{(17+6+3+1+0)} = 3.44$$

$$\text{Importance Index} = \frac{3.44}{4} x\ 100 = 86.0\%$$

3.4 SIZE DETERMINATION

In this study the sample survey was selected from "Commercial Directory", first issue 1991, published by the Chamber of Commerce and Industry, Eastern Province. There are 430 building maintenance contractors in the Eastern Province of Saudi Arabia.

The minimum number of building maintenance contractors that represent the total population (sample) can be calculated based on the following formula (Kendall, 1970):

$$n = \frac{n'}{\left(1 + \frac{n'}{N}\right)}, \quad n' = \frac{S^2}{V^2}$$

where;

n =	sample size
N =	size of the finite population
S^2 =	The variation of population elements or the maximum variance estimate. It is estimated by $S^2 = P\,(1-P)$, where P is the proportion of the population, the maximum value is chosen at $P = 0.5$.
V =	Standard deviation of the sampling distribution. 0.05 is a reasonable estimate of V.
n' =	The value of contractor distribution.

By applying the above formula on the building maintenance contractor population of 430 contractors, the sample size will be:

$$\hat{n} = \frac{(0.5)^2}{(0.05)^2} = 100 \text{ and } n = \frac{100}{1 + \frac{100}{430}} = 82 \text{ contractors}$$

The minimum required response rate was (82/430) x 100 = 19%. However, the actual response rate was (122/430) x 100 = 28%, which exceeded the minimum requirement.

In this research, the population of the contracting firms was divided into three categories according to the firm size. In making estimates concerning the different categories of the population, the sample size must be weighted to the total population sample size using the response rate to meet the minimum size requirement.

Small (Number of Employees 1 - 10)

The sample size surveyed for this category was 83 contractors. The estimated statistical sample size = 83 x .19 = 16 contractors.

Medium (Number of Employees 11 -50)

The sample size surveyed for this category was 319 contractors. The estimated statistical sample size = 319 x .19 = 61 contractors

Large (Number of Employees > 50)

The sample size surveyed for this category was 28 contractors. The estimated statistical sample size $= 28 \times .19 = 5$ contractors.

3.4.1 Sample Precision

In order to quantify the sample size precision for each category size, the confidence level and the interval of estimate were considered. Both the confidence level and the interval of estimate are important determinants of the actual sample precision.

The interval estimate with a 95 percent confidence level:

$$I.E. = \pm\ 1.96\ V \qquad \text{(Berenson, 1988)}$$

$$= \pm\ .098 \approx \pm\ 0.1$$

where;

$\pm 1.96\ V$	=	0.95 confidence level for estimating interval within which to expect population mean.
$\pm\ 1.96$	=	Area under the normal distribution curve within which to expect the population proportion.
V	=	Standard deviation of the sampling distributtion 0.05 is a reasonable estimate of V.

The actual sample size precision was calculated by multiplying the I.E. with the actual statistical sample size. For small contractors the actual statistical sample size was 16 contractors and the sample precision $= 16 \times .1 \pm 1.6 \approx \pm 2$.

For medium contractors the actual statistical sample size was 61 contractors and the sample precision = 61 x 0.1 = ± 6.1 ≈ ± 6.

For large contractors the actual statistical sample size was 5 contractors and the sample precision = 5 x 0.1 = ± 0.5 ≈ ± 1.

Table 3.3 shows the surveyed sample size and the actual statistical sample size.

Table 3.3: Surveyed Sample Size Versus Actual Statistical Sample Size

Sample	Surveyed Sample Size	Actual Statistical Sample Size
Total	430	82 ± 9
Small	83	16 ± 2
Medium	319	61 ± 6
Large	28	5 ± 1

Table 3.4 shows the total samples and the respondent contractors in the three categories.

Table 3.4: Number of Companies Selected and Participated in Answering the Questionnaire.

No.	Description	Number of Questionnaire	Percentage
1	Total Number of questionnaires distributed	430	100
2	Total number of completed questionnaires returned	122	28
3	Number of contractors who did not respond.	310	72

The number of respondent contractors in the three categories is shown in Table 3.5.

Table 3.5: Number of Respondent Contractors in the Three Categories.

Class	Description	Number of Questionnaires	Percentage
Small	Number of questionnaires distributed	83	100
	Number of completed questionnaires returned	38	46
	Number of contractors who did not respond.	45	54
Medium	Number of questionnaires distributed	319	100
	Number of completed questionnaires returned	57	18
	Number of contractors who did not respond.	262	82
Large	Number of questionnaires distributed	28	100
	Number of completed questionnaires returned	27	96
	Number of contractors who did not respond.	1	4

CHAPTER 4

RANKING OF THE ASSESSMENT OF SAFETY LEVEL EVALUATION FACTORS / CRITERIA

4.0 INTRODUCTION

The 122 questionnaires received were statistically analyzed to calculate the average value for each safety factor for the purpose of ranking these safety factors according to the highest average value and importance index for each of the different sizes of maintenance contractors. The results of the ranking of the safety factors were compared among the different sizes of maintenance contractors.

4.1 RANKING OF SAFETY FACTORS AVERAGE VALUE

The average value for each safety factor were calculated using the same method shown previously in Table 3.2.

The average value and the importance index of the safety factors presented on the questionnaire was calculated for the different sizes of maintenance contractors.

4.1.1 Safety Factors Indicated By Small Contractors

The average value and the importance index of the safety factors for the small contractors were calculated and presented in Table 4.1. The number of participants for each option of the safety factors are also listed in Table 4.1. It is shown in Table 4.1 that the most important safety factors indicated by the small contractor participants are "Providing Safety Award", "Top Management Concern in Decreasing Frequency Rate", "Financial Saving as a Result of Applying Safety" and "Accident Costs Allocation". The safety factors shown in Table 4.1 can be classified into four categories based on the range of the importance index values.

The most important category (Importance Index between 87.5-100%) includes safety factors 1 through 4. The very important category (Importance Index between 62.5-87.5%) includes the intermediate safety factors 5 through 36. The important category (Importance Index between 37.5 - 62.5%) includes safety factors 37 through 41 and the less important category (Importance Index between 12.5 - 37.5%) includes safety factor 42.

Table 4.1: Summary Report of Safety Factors for Small Maintenance Contractors Ranked by their Importance Index

No.	Safety Factors	Always / Yes	Most of the Time	Sometimes	Rarely	Never / No	Avg. Value	Importance Index	Importance Category
		4	3	2	1	0			
		No. of Participants Marked							
1	Providing Safety Awards	29	9	0	0	0	3.76	94.08	
2	Top Management concern in Decreasing Frequency Rate	23	15	0	0	0	3.61	90.13	
3	Financial Saving as a result of applying safety	26	7	5	0	0	3.55	88.82	87.5-100
4	Accident costs allocation	25	10	2	1	0	3.55	88.82	
5	Conducting safety inspections	23	12	0	2	1	3.42	85.50	
6	Availability of hazard recognition and Control Procedures	21	13	2	1	6	3.37	84.30	
7	Correction of Unsafe conditions	21	11	0	6	0	3.24	80.92	
8	Continuous practicing of safety by Safety Professionals	20	11	3	3	1	3.21	80.20	
9	Continuous Practicing of Safety by Top Management	24	6	3	0	5	3.16	79.00	62.5 -87.5
10	Providing instructions on personal Protective Equipment	11	21	5	1	0	3.11	77.63	
11	Providing instructions on fire Protection and Prevention	11	20	7	0	0	3.11	77.63	
12	Providing instructions on accident investigation	10	21	6	1	0	3.05	76.30	
13	Providing safety training	18	10	5	3	2	3.03	75.70	
14	Reporting of accidents to social insurance	18	9	6	4	1	3.03	75.70	
15	Applying Previous Accident Investigation Findings in preventing Future Accident	9	25	2	0	2	3.03	75.70	

Continued Table 4.1

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
16	The use of frequency rates in modifying safety processes	17	11	4	5	1	3.00	75.00	62.5-87.5
17	Conducting safety meetings for safety Professionals	13	15	7	3	0	3.00	75.00	
18	Timing corrections of unsafe conditions by Professionals	19	9	2	5	3	2.95	73.80	
19	The use of frequency rates in preventing future accidents	16	12	4	3	3	2.92	73.00	
20	Participation of Safety Professional in Developing Safety Programs	19	8	3	4	4	2.90	72.40	
21	Performing periodic hazard reviews	10	23	0	0	5	2.87	71.80	
22	Providing instructions on first aid procedures	9	23	1	2	3	2.87	71.80	
23	The existence of safety professional/department	27	0	0	0	11	2.84	71.00	
24	Performing foreman safety training	19	7	4	3	5	2.84	71.00	
25	The use of frequency rates in determining Safety Objectives	15	8	9	6	0	2.84	71.00	
26	The use of frequency rates in motivating the Workers	17	10	3	3	5	2.82	70.50	
27	Performing accident Analysis and Investigation	13	17	2	0	6	2.82	70.50	
28	The Use of Frequency Rates in determining Management Movement towards the desired objective	11	13	10	4	0	2.82	70.50	
29	Documentation of unsafe conditions	16	8	7	4	3	2.79	69.70	
30	Safety consideration in the bid process	14	11	5	5	3	2.72	68.00	
31	The reinforcement of safety rules by Safety Professionals	15	9	8	0	6	2.71	67.80	

Continued Table 4.1

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
32	Reporting of accidents to owner representative	12	17	1	2	6	2.71	67.80	37.5-62.5
33	Providing instructions on safe work practices	14	13	1	5	5	2.68	67.10	
34	Conducting safety meetings	15	8	6	3	6	2.61	65.30	
35	Reporting of accidents to the top management	14	11	2	5	6	2.58	64.50	
36	Clear Management safety policy	7	21	2	2	6	2.55	63.80	
37	Providing Instructions on Emergency Procedures	14	7	7	0	10	2.40	60.00	
38	The Use of frequency rates in measuring Safety Accomplishment	8	17	0	8	5	2.40	60.00	
39	The use of frequency rates in long term Planning	6	12	11	3	6	2.23	56.00	
40	The use of safety program or manual	20	0	0	0	18	2.11	52.80	
41	The use of Frequency Rates as short Term Performance Indicators	5	10	3	12	8	1.80	45.00	
42	Providing Orientation Program for new Employees	13	0	0	0	25	1.37	34.30	12.5-37.5

4.1.2 Safety Factors Indicated by Medium Contractors

The average value and the importance index of the safety factors for medium contractors are listed on Table 4.2. It is shown in Table 4.2 that the most important safety factors indicated by the medium contractor participants are "Top Management Concern in Decreasing Frequency Rate", "The Use of Frequency Rates as Short Term Performance Indicator" and "Safety Consideration in the Bid Process". The safety factors were classified into three categories based on the range of importance index values.

The most important category (Importance Index between 87.5 - 100%) includes safety factors 1 through 3. The very important category (Importance Index between 62.5 - 87.5%) includes the safety factors from 4 through 33. The important category for medium contractors (Importance Index between 37.5 - 62.5%) includes safety factors 34 through 42.

Table 4.2: Summary Report of Safety Factors for Medium Maintenance Contractors Ranked by their Importance Index

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
1	Top Management Concern in Decreasing Frequency Rate	52	5	0	0	0	3.91	97.81	87.5 - 100
2	The Use of Frequency Rates as Short Term Performance Indicators	41	16	0	0	0	3.72	92.98	
3	Safety Consideration in the Bid Process	38	15	4	0	0	3.60	89.91	
4	Financial Saving as a Result of Applying Safety	37	13	3	4	0	3.46	86.40	62.5-87.5
5	The Existence of Safety Professional/ Department	49	0	0	0	8	3.44	86.00	
6	Continuous Practicing of Safety by Safety Professionals	30	20	7	0	0	3.40	85.09	
7	The Use of Frequency Rates in Motivating the Workers	31	15	10	1	0	3.33	83.33	
8	Conducting Safety Meetings	23	29	3	2	0	3.28	82.02	
9	The Use of Frequency Rates in Preventing Future Accidents	32	17	2	2	4	3.25	81.30	
10	The Use of Frequency Rates in Determining Safety Objective	23	26	7	0	0	3.23	80.70	
11	Correction of Unsafe Conditions	20	31	4	1	1	3.20	80.00	

Continued Table 4.2

		Always / Yes	Most of the Time	Sometimes	Rarely	Never / No			
		4	3	2	1	0			
No.	Safety Factors	No. of Participants Marked					Avg. Value	Importance Index	Importance Category
12	Conducting Safety Inspections	34	14	0	3	6	3.18	79.50	
13	The Reinforcement of Safety Rules by Safety Professionals	27	21	0	7	2	3.12	78.00	
14	The Use of Frequency Rates in Modifying Safety Processes	13	36	6	0	2	3.02	75.40	
15	Participation of Safety Professional in Developing Safety Programs	16	27	9	4	1	2.93	73.30	62.5-87.5
16	Documentation of Unsafe Conditions	19	25	4	6	3	2.90	72.50	
17	Providing Instructions on Safe Work Practices	3	47	5	2	0	2.90	72.50	
18	Clear Management Safety Policy	15	29	6	4	3	2.86	71.50	
19	Performing Periodic Hazard Reviews	12	29	12	4	0	2.86	71.50	
20	Timing Corrections of Unsafe Conditions by Safety Professionals	9	37	5	4	2	2.82	70.50	

Continued Table 4.2

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
21	The Use of Safety Program or Manual	40	0	0	0	17	2.81	7.30	
22	Performing Accident Analysis and Investigation	13	27	11	5	1	2.81	7.30	
23	Applying Previous Accident Investigation Finding in Preventing Future Accident	12	31	6	7	3	2.81	7.30	
24	Providing Instructions on Accident Investigation	5	41	7	2	2	2.80	70.00	
25	Providing Orientation Program for New employee	4	40	10	1	2	2.75	68.80	
26	The Use of Frequency Rates in Determining Management Movement Towards the Desired Objectives.	14	21	17	3	2	2.74	68.50	62.87.5
27	Providing Safety Awards	10	33	7	1	6	2.70	67.50	
28	The Use of Frequency Rates in Measuring Safety Accomplishment	5	41	0	10	1	2.68	67.00	
29	Availability of Hazard Recognition and Control Procedures	3	39	12	0	3	2.68	67.00	
30	Continuous Practicing of Safety by Top Management	7	35	8	2	5	2.65	66.30	
31	The use of Frequency Rates in Long Term Planning	8	33	6	6	4	2.61	65.30	
32	Accident Costs Allocation	6	38	3	5	5	2.61	65.30	
33	Performing Foreman Safety Training	4	33	15	3	2	2.60	65.00	
34	Providing Safety Training	11	19	15	10	2	2.47	61.80	37.5-62.5

Continued Table 4.2

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
35	Providing Instructions on Emergency Procedures	3	23	25	3	3	2.35	58.80	
36	Reporting of Accidents to the Top Management	2	27	19	3	6	2.28	57.00	37.5 - 62.5
37	Reporting of Accidents to Social Insurance	7	12	29	6	3	2.25	56.30	
38	Providing instructions on Fire Protection and Prevention	2	13	35	7	0	2.18	54.50	
39	Conducting Safety Meetings for Safety Professionals	6	9	31	9	2	2.14	53.50	
40	Providing Instructions on Personal Protective Equipment	4	15	27	7	4	2.14	53.50	
41	Reporting of Accidents to Owner Representative	3	11	23	17	3	1.90	47.50	
42	Providing Instructions on First Aid Procedures	3	7	29	15	3	1.86	46.50	

4.1.3 Safety Factors Indicated By Large Contractors

For large contractors the average value, the importance index and the number of participants for each option of the safety factors are presented on Table 4.3. Table 4.3 shows that the major safety factors indicated by the large contractor participants are "Continuous Practicing of Safety by Top Management", "The Use of Safety Program or Manual", "The Existence of Safety Professional/Department", "Safety Consideration in the Bid Process", and "Top Management Concern in Decreasing Frequency Rate". The safety factors were classified into four categories according to the range of importance index values.

The most important category (Importance Index between 87.5 - 100%) includes safety factors 1 through 5. The very important category (Importance Index between 62.5 - 87.5%) includes the safety factors from 6 through 33. The important category for large contractors (Importance Index between 37.5 - 62.5%) includes safety factors 34 through 41, and the less important category (Importance Index 12.5 - 37.5%) includes safety factor 42.

Table 4.3: Summary Report of Safety Factors for Large Maintenance Contractors Ranked by their Importance Index

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
1	Continuous Practicing of Safety by Top Management	21	6	0	0	0	3.78	94.44	87.5-100
2	The Use of Safety Program or Manual	20	7	0	0	0	3.74	93.52	
3	The Existence of Safety Professional / Department	19	5	3	0	0	3.59	89.81	
4	Safety Consideration in the Bid Process	18	7	1	1	0	3.56	88.89	
5	Top Management Concern in Decreasing Frequency Rate	17	7	3	0	0	3.52	87.96	
6	Clear Management Safety Policy	14	12	1	0	0	3.48	87.04	62.5-87.5
7	The Use of Frequency Rates as Short Term Performance Indicators	15	9	2	1	0	3.41	85.30	
8	The Use of Frequency Rates in Long Term Planning	13	12	0	1	1	3.30	82.50	
9	Providing Orientation Program for new employees	11	13	2	1	0	3.30	85.50	
10	Accident Costs Allocation	12	8	6	1	0	3.15	78.70	
11	Providing Instructions on Safe Work Practices	10	12	3	2	0	3.11	77.78	
12	Providing Safety Training	9	13	3	2	0	3.07	76.85	

Continued Table 4.3

No.	Safety Factors	Always / Yes	Most of the Time	Sometimes	Rarely	Never / No	Avg. Value	Importance Index	Importance Category
		4	3	2	1	0			
		No. of Participants Marked							
13	Financial Saving as a Result of Applying Safety	9	12	4	2	0	3.04	75.93	62.5 - 87.5
14	The Use of Frequency Rates in Motivating the Workers	8	14	3	2	0	3.04	75.93	
15	Providing Instructions on Fire Protection and Prevention	6	16	4	1	0	3.00	75.00	
16	Conducting Safety Inspections	7	13	6	1	0	2.96	74.07	
17	Availability of Hazard Recognition and Control Procedures	5	17	4	1	0	2.96	74.07	
18	Providing Instructions on Emergency Procedures	7	13	5	2	0	2.93	73.15	
19	The Use of Frequency Rates in Modifying Safety Processes	3	20	3	1	0	2.93	73.15	
20	Providing Instructions on First Aid Procedures	7	11	7	3	0	2.89	72.30	
21	Providing Safety Awards	5	17	3	1	1	2.89	72.30	
22	Performing Foreman Safety Training	3	18	6	0	0	2.89	72.30	
23	Providing Instructions on Personal Protective Equipment	7	12	5	3	0	2.85	71.30	
24	Conducting Safety Meeting for Safety Professional	6	15	3	2	1	2.85	71.30	
25	The Use of Frequency Rates in Determining Safety Objectives	2	19	5	1	0	2.81	70.37	
26	Participation of Safety Professional in Developing Safety Programs	2	18	6	1	0	2.78	69.44	
27	Correction of Unsafe Conditions	4	16	4	1	2	2.70	67.50	
28	Reporting of Accident to the Top Management	3	17	4	2	1	2.70	67.50	

Continued Table 4.3

No.	Safety Factors	Always / Yes (4)	Most of the Time (3)	Sometimes (2)	Rarely (1)	Never / No (0)	Avg. Value	Importance Index	Importance Category
		No. of Participants Marked							
29	The Use of Frequency Rates in Preventing Future Accidents	2	15	9	1	0	2.67	66.67	62.5-87.5
30	Performing Accident Analysis & Investigation	2	13	12	0	0	2.63	65.74	
31	Performing Periodic Hazard Reviews	3	9	15	0	0	2.56	63.89	
32	Documentation of Unsafe Conditions	4	15	3	1	4	2.52	63.00	
33	Reporting of Accident to Social Insurance	3	10	12	2	0	2.52	63.00	
34	Conducting Safety Meetings	3	12	8	3	1	2.48	62.00	37.5 - 62.5
35	Continuous Practicing of Safety by Safety Professionals	3	12	7	2	3	2.37	59.30	
36	Applying Previous Accident Investigation Findings in Preventing Future Accidents	2	7	17	1	0	2.37	59.30	
37	Timing Corrections of Unsafe Conditions by Safety Professionals	3	7	13	4	0	2.33	58.33	
38	The Reinforcement of Safety Rules by Safety Professionals	3	6	14	4	0	2.30	57.41	
39	Providing Instructions on Accident Investigation	2	3	19	1	2	2.10	52.50	
40	Reporting of Accident to Owner Representative	2	5	15	1	4	2.00	50.00	
41	The Use of Frequency Rates in Determining Management Movement Towards the Desired Objectives	2	5	13	2	5	1.89	47.30	
42	The Use of Frequency Rates in Measuring Safety Accomplishment	2	2	12	2	9	1.48	37.00	12.5-37.5

4.2 SAFETY FACTOR RANKING AMONG DIFFERENT SIZES OF MAINTENANCE CONTRACTORS

The results of the ranking of safety factors were compared among different sizes of maintenance contractors. The result is presented in Table 4.4; as noted, the safety factors indicated as important for one size of contractors are different from those indicated by the other two sizes of contractors. The ranking of the different factors will be tested using Kendall Concordance analysis for agreement.

Table 4.4: Safety Factors Ranking Among the Different Sizes of Maintenance Contractors

No	SAFETY FACTORS	SMALL		MEDIUM		LARGE	
		Avg. Value	Rank	Avg. Value	Rank	Avg. Value	Rank
1	The Use of Safety Program or Manual	2.11	40	2.81	21	3.74	2
2	The Existence of Safety Professional/Department	2.84	23	3.44	5	3.60	3
3	Safety Consideration in the Bid Process	2.72	30	3.6	3	3.56	4
4	Clear Management Safety Policy	2.55	36	2.86	18	3.48	6
5	Financial Saving as a Result of Applying Safety	3.55	3	3.46	4	3.04	13
6	Accident costs Allocation	3.55	4	2.61	32	3.15	10
7	Top Management Concern in Decreasing Frequency Rate	3.61	2	3.91	1	3.52	5
8	Continuous practicing of Safety by Top Management	3.16	9	2.65	30	3.78	1
9	The Use of Frequency Rates as Short Term Performance Indicators	1.8	41	3.72	2	3.41	7
10	The Use of Frequency Rates in Long Term Planning	2.23	39	2.61	31	3.30	8
11	The Use of Frequency Rates in Determining Safety Objectives	2.84	25	3.23	10	2.81	25
12	The Use of Frequency Rates in Modifying Safety Processes	3	16	3.02	14	2.93	19
13	The Use of Frequency Rates in Preventing Future Accident	2.92	19	3.25	9	2.67	29
14	The Use of Frequency Rates in Motivating the Workers	2.82	26	3.33	7	3.04	14
15	The Use of Frequency Rates in Measuring Safety Accomplishment	2.4	38	2.68	28	1.48	42

Continued Table 4.4

No	SAFETY FACTORS	SMALL		MEDIUM		LARGE	
		Avg. Value	Rank	Avg. Value	Rank	Avg. Value	Rank
16	The Use of Frequency Rates in Determining Management Movement Towards the Desire Objectives.	2.82	2.8	2.74	26	1.89	41
17	Conducting Safety Inspections	3.42	5	3.18	12	2.96	16
18	Documentation of Unsafe Conditions	2.79	29	2.90	16	2.52	32
19	Correction of Unsafe Conditions	3.23	7	3.20	11	2.70	27
20	Continuous Practicing of Safety by Safety Professionals	3.21	8	3.40	6	2.37	35
21	The Reinforcement of Safety Rules by Safety Professionals	2.71	31	3.12	13	2.30	38
22	Timing Corrections of Unsafe Conditions by Safety Professionals	2.95	18	2.82	20	2.33	37
23	Participation of Safety Professional in Developing Safety Programs	2.90	20	2.93	15	2.78	26
24	Conducting Safety Meetings	2.61	34	3.28	8	2.48	34
25	Reporting of Accidents to the Top Management	2.58	35	2.28	36	2.70	28
26	Reporting of Accidents to Social Insurance	3.03	14	2.25	37	2.52	33
27	Reporting of Accidents to Owner Representative	2.71	32	1.90	41	2.00	40
28	Providing Safety Awards	3.76	1	2.70	27	2.89	21
29	Availability of Hazard Recognition and Control Procedures	3.37	6	2.68	29	2.96	17
30	Performing Periodic Hazard Reviews	2.87	21	2.86	19	2.56	31

Continued Table 4.4

No	SAFETY FACTORS	SMALL		MEDIUM		LARGE	
		Avg. Value	Rank	Avg. Value	Rank	Avg. Value	Rank
31	Providing Orientation Program for New Employee	1.37	42	2.75	25	3.30	9
32	Providing Instructions on Personal Protective Equipment	3.11	10	2.14	40	2.85	23
33	Providing Instructions on Safe Work Practices	2.68	33	2.90	17	3.11	11
34	Providing Instructions on Emergency Procedures	2.40	37	2.35	35	2.93	18
35	Providing Instructions on Fire Aid Procedures	2.87	22	1.86	42	2.89	20
36	Providing Instructions on Accident Investigation	3.05	12	2.80	24	2.10	39
37	Providing Instructions on Fire Protection and Prevention	3.11	11	2.18	38	3.00	15
38	Providing Safety Training	3.03	13	2.47	34	3.10	12
39	Conducting Safety Meetings for Safety Professionals	3	17	2.14	39	2.85	24
40	Performing Foreman Safety Training	2.84	24	2.60	33	2.89	22
41	Performing Accident Analysis and Investigation	2.82	27	2.81	22	2.63	30
42	Applying Previous Accident Investigation Findings in Preventing Future Accidents.	3.03	15	2.81	23	2.37	36

4.3 KENDALL CONCORDANCE ANALYSIS FOR AGREEMENT

The Kendall coefficient of concordance (W) is a statistic used to measure how good an agreement or association is among sets of rankings.

The statistic varies between 0 and 1 regardless of the number of sets of rankings. That is, a coefficient of W =1 indicates a perfect agreement or high degree of association and W = 0 indicates no agreement. The Kendall coefficient of concordance is given by the following formula;

$$W = \frac{\sum_{i=1}^{i=42} (R_i - R)^2}{n(n2 - 1)/12} \quad \text{(Kaming, 1996)}$$

Where;

n	=	number of factors or criteria = 42
Ri	=	The mean of the ranks assigned to each factor. For example; the mean of the ranks assigned to the first factor, $R_i = \frac{40+21+2}{3} = 21$
R	=	Grand mean or average of the mean of the ranks assigned to each factor.
R	=	$= \frac{\sum_{i=1}^{i=42} R_i}{n} =$

$$= \frac{R_1 + R_2 + \dots\dots\dots + R_n}{n}$$

$$= \frac{R_1 + R_2 + \dots\dots\dots\dots + R_{42}}{42}$$

$$= \frac{21.00 + 10.33 + \dots + 24.67}{42} = \frac{902.98}{42} = 21.50$$

The rank values of the safety factors were compared for the different sizes of contractors using Kendall Concordance analysis. The mean of the ranks assigned to each factor was calculated and is presented in Table 4.5.

$$\sum_{i=1}^{i=42} (R_i - \bar{R})^2$$

$$\sum_{i=1}^{i=42} (R_i - 21.50)^2 = (21.00-21.50)^2 + (10.33-21.50)^2$$

$$+ (12.33 - 21.50)^2 + \dots\dots + (26.33-21.50)^2 + (24.67-21.50)^2 = 2298.51$$

The Kendall coefficient of concordance:

$$W = \frac{2298.51}{42\,(42^2 - 1)\,/12} = \frac{2298.51}{6170.50} = 0.373$$

By employing Kendall concordance analysis the best estimate of the true ranking of the safety factors is provided where W is significant by the order of various sums of ranks, then the best true ranking is provided by the mean of the ranks.

Kendall concordance analysis provided significant ranking of safety factors indicating that top management concern in decreasing frequency rate ranked first. Financial saving as a result of applying safety ranked the second, and the existence of safety professional / department ranked as the third safety factor.

4.3.1 Testing the Significance of Kendall Coefficient of Concordance

If the number of factors n is smaller than seven, a statistical table (Appendix B) must be used to test the significance at various levels. Where the number of factors n is greater than seven, then the chi-square value for this statistic is given by:

$$\chi^2 = K\,(n-1)\,W \qquad \text{(Kaming, 1996)}$$

where;

K = Number of categories or groups

n = Number of factors

W = Kendall coefficient of concordance

is approximately distributed as the Chi-square distribution with n-1 degrees of freedom (Appendix C). The Chi-square (χ^2) test is mainly used to test the null hypothesis; that K sets of ranks are unrelated or independent.

W = 0.373 expresses the degree of agreement among the three sizes of contractors. Since the number of factors (n = 42) is greater than seven we calculate the Chi-square value for K=3 (Number of contractors catagories) , n = 42 (Number of safety factors), and W = 0.373:

$$\chi^2 = 3\ (42\text{-}1) * 0.373 = 45.88$$

Referring to the critical values of Chi-square distribution table (Appendix 3) with a degree of freedom (DF):

$$DF = n - 1 = 42 - 1 = 41$$

The critical value of χ_c^2 = 56.94 (obtained from the critical value of the Chi-square distribution) is greater than the observed value χ^2 = 45.88 in a probability of occurrence under the null hypothesis of $P < 0.05$.

We can conclude with confidence that the level of agreement among these three sizes of contractors is lower than it would be by chance. The high probability under null hypothesis associated with observed value of W allows the acceptance of the null hypothesis; that the rankings of these three sizes of contractors are unrelated to each other. Therefore, we conclude that there is no agreement among the three sizes of contractors.

Table 4.5: Agreement of Ranking of the Safety Factors

No.	SAFETY FACTORS	Small Rank	Medium Rank	Large Rank	Sum of Ranks	Mean of Ranks	Overall Ranking
1	The Use of Safety Program or Manual	40	21	2	63	21.00	21
2	The Existence of Safety Professional/Department	23	5	3	31	10.33	3
3	Safety Consideration in the Bid Process	30	3	4	37	12.33	5
4	Clear Management Safety Policy	36	18	6	60	20.00	17
5	Financial Saving as a Result of Applying Safety	3	4	13	20	6.67	2
6	Accident costs Allocation	4	32	10	46	15.33	8
7	Top Management Concern in Decreasing Frequency Rate	2	1	5	8	2.67	1
8	Continuous practicing of Safety by Top Management	9	30	1	40	13.33	6
9	The Use of Frequency Rates as Short Term Performance Indicators	41	2	7	50	16.67	13
10	The Use of Frequency Rates in Long Term Planning	39	31	8	78	26.00	31
11	The Use of Frequency Rates in Determining Safety Objectives	25	10	25	60	20.00	18
12	The Use of Frequency Rates in Modifying Safety Processes	16	14	19	49	16.33	10
13	The Use of Frequency Rates in Preventing Future Accident	19	9	29	57	19.00	15
14	The Use of Frequency Rates in Motivating the Workers	26	7	14	47	15.67	9
15	The Use of Frequency Rates in Measuring Safety Accomplishment	38	28	42	108	36.00	41

Continued Table 4.5

No.	SAFETY FACTORS	Small Rank	Medium Rank	Large Rank	Sum of Ranks	Mean of Ranks	Overall Ranking
16	The Use of Frequency Rates in Determining Management Movement Towards the Desired Objectives.	28	26	41	95	31.67	39
17	Conducting Safety Inspections	5	12	16	33	11.00	4
18	Documentation of Unsafe Conditions	29	16	32	77	25.67	30
19	Correction of Unsafe Conditions	7	11	27	45	15.00	7
20	Continuous Practicing of Safety by Safety Professionals	8	6	35	49	16.33	11
21	The Reinforcement of Safety Rules by Safety Professionals	31	13	38	82	27.33	35
22	Timing Corrections of Unsafe Conditions by Safety Professionals	18	20	37	75	25.00	27
23	Participation of Safety Professional in Developing Safety Programs	20	15	26	61	20.33	19
24	Conducting Safety Meetings	34	8	34	76	25.33	28
25	Reporting of Accidents to the Top Management	35	36	28	99	33.00	40
26	Reporting of Accidents to Social Insurance	14	37	33	84	28.00	36
27	Reporting of Accidents to Owner Representative	32	41	40	113	37.67	42
28	Providing Safety Awards	1	27	21	49	16.33	12
29	Availability of Hazard Recognition and Control Procedures.	6	29	17	52	17.33	14
30	Performing Periodic Hazard Reviews	21	19	31	71	23.67	23

Continued Table 4.5

No.	SAFETY FACTORS	Small Rank	Medium Rank	Large Rank	Sum of Ranks	Mean of Ranks	Overall Ranking
31	Providing Orientation Program for New Employee	42	25	9	76	25.33	29
32	Providing Instructions on Personal Protective Equipment	10	40	23	73	24.33	24
33	Providing Instructions on Safe Work Practices	33	17	11	61	20.33	20
34	Providing Instructions on Emergency Procedures	37	35	18	90	30.00	38
35	Providing Instructions on Fire Aid Procedures	22	42	20	84	28.00	37
36	Providing Instructions on Accident Investigation	12	24	39	75	25.00	26
37	Providing Instructions on Fire Protection and Prevention	11	38	15	64	21.33	22
38	Providing Safety Training	13	34	12	59	19.67	16
39	Conducting Safety Meetings for Safety Professionals	17	39	24	80	26.67	34
40	Performing Foreman Safety Training	24	33	22	79	26.33	32
41	Performing Accident Analysis and Investigation	27	22	30	79	26.33	33
42	Applying Previous Accident Investigation Findings in Preventing Future Accidents.	15	23	36	74	24.67	25
	Sum of the Mean of the Ranks					902.98	

CHAPTER 5

SAFETY ASSESSMENT RESULTS

5.0 INTRODUCTION

The 122 questionnaires received were analyzed to calculate the contractor frequency rate, the contractor safety attitude score and the contractor safety performance level for each contractor.

The contractors' safety performance levels were used to calculate the safety performance level indexes for the different sizes of maintenance contractors.

5.1 FREQUENCY RATE

Frequency rate (FR) is a statistic used to measure safety performance. It is the most common measure of safety accomplishment. It measures safety performance in terms of the number of accidents. Frequency rates are usually used as quantitative indicators to evaluate safety changes, measure safety progress and warn of potential problems. They can be used as a feedback mechanism for making appropriate adjustments to the safety process. This involves analyzing the gathered data and accident statistics and interpreting safety process information to detect areas where corrective action is needed to prevent recurrence.

Frequency rate is considered as a tool to assess and reflect contractor safety performance. It is used to compare accident and injury statistics either within a contractor organization or within an industry.

The ANSI (American National Standards Institute) Z16.1 or the frequency rate is the number of disabling (lost-time) injuries per million employee-hours worked. Mathematically, the formula is expressed as:

$$\text{Frequency Rate} = \frac{\text{Number of disabling injuries x 1,000,000}}{\text{Employees-hours worked}}$$

where;

Number of disabling injuries: are lost-time or lost-day cases where the injured worker needs medical attention and one or more days off work subsequent to the date of injury (10). Disabling injuries include four types of injuries (10):

(1) Deaths

(2) Permanent Total Disabilities

(3) Permanent Partial Disabilities

(4) Temporary Total Disabilities

Employees-hours worked: are the hours of exposure or the workorder hours.

1,000,000 is a scaling number used to keep a common base for all rates.

The frequency rate for the received questionnaires was calculated and is presented in Table 5.1 for small contractors, Table 5.2 for medium contractors, and Table 5.3 for large contractors.

Table 5.1: Calculated Frequency Rates for Small Contractors

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
1	1	4274	234
2	1	3163	316
3	1	3184	314
4	1	3275	306
5	2	6453	310
6	1	4152	241
7	1	3560	281
8	1	4820	208
9	2	6860	292
10	1	3304	303
11	1	3920	255
12	1	3230	310
13	1	4460	224
14	1	3690	271
15	1	3380	300
16	1	3818	262
17	1	2870	348
18	1	3700	271
19	1	2960	340
20	2	5800	345
21	1	4175	240
22	1	6700	149
23	1	5670	177

Continued Table 5.1

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
24	1	4200	238
25	1	4050	247
26	1	6205	161
27	1	5470	183
28	1	4090	245
29	2	6370	314
30	2	6110	327
31	1	4130	243
32	1	6575	152
33	1	4750	211
34	0	4323	0
35	0	4300	0
36	0	5427	0
37	0	2136	0
38	0	4500	0

Table 5.2: Calculated Frequency Rates for Medium Contractors

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
1	1	6200	162
2	1	7150	140
3	2	9450	212
4	2	7500	267
5	2	8300	241
6	1	8100	124
7	1	8700	115
8	3	9800	305
9	2	11520	174
10	1	11150	90
11	1	7212	139
12	2	9430	212
13	1	6640	151
14	1	7230	138
15	2	8700	230
16	1	9540	105
17	3	8930	336
18	1	9720	103
19	1	8710	115
20	4	12310	325
21	2	12072	166
22	1	11500	87

Continued Table 5.2

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
23	2	12800	157
24	4	11670	343
25	1	12335	81
26	2	13250	151
27	1	7423	135
28	1	10710	94
29	2	9325	215
30	1	8215	122
31	1	9028	111
32	1	11214	89
33	2	12114	165
34	3	11327	265
35	3	9421	319
36	1	11630	86
37	2	12915	155
38	1	10732	93
39	1	7321	137
40	1	6428	156
41	1	7711	130
42	1	8417	119
43	1	12550	80

Continued Table 5.2

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
44	4	12670	316
45	3	11390	263
46	1	9623	104
47	2	8727	229
48	1	4230	237
49	1	4680	214
50	3	12840	234
51	2	11425	175
52	3	9763	308
53	0	4270	0
54	0	6800	0
55	0	9050	0
56	0	10200	0
57	0	11230	0

Table 5.3: Calculated Frequency Rates for Large Contractors

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
1	3	12096	248
2	1	11120	90
3	1	10121	99
4	1	7920	127
5	1	11230	89
6	4	12415	322
7	2	9423	212
8	1	8320	120
9	1	6115	164
10	1	7320	137
11	1	8840	113
12	2	7212	277
13	1	8210	122
14	1	8090	124
15	1	9610	104
16	1	11318	89
17	1	6228	161
18	2	10520	190
19	1	12313	81
20	2	12060	166
21	1	8453	118

Continued Table 5.3

Contractor No.	Number of Disabling Injuries	Number of Workorder-Hours	Frequency Rate
22	1	11400	88
23	1	6250	160
24	1	6617	151
25	1	6023	166
26	1	7317	137
27	2	11215	178

5.2 CONTRACTOR SAFETY ATTITUDE SCORE

The Contractor Safety Attitude Score (SAS) was determined for each contractor. It is the sum of the weight of the safety factors evaluated by the particular contractor.

The received questionnaires were analyzed and safety attitude score was calculated for each contractor of the three sizes. The safety attitude scores for the participating contractors are listed in Table 5.4 for small contractors, Table 5.5 for medium contractors, and Table 5.6 for large contractors. The maximum contractor safety attitude score was 152 and the minimum was 39.

Table 5.4: Safety Attitude Score for Small Contractors

Contractor No.	Safety Attitude Score
1	77
2	51
3	68
4	83
5	53
6	60
7	44
8	93
9	59
10	69
11	62
12	44
13	79
14	86
15	72
16	91
17	47
18	78
19	83
20	41
21	83
22	118
23	98
24	89
25	65

Continued Table 5.4

Contractor No.	Safety Attitude Score
26	116
27	107
28	73
29	57
30	46
31	90
32	105
33	87
34	129
35	97
36	81
37	123
38	126

Table 5.5: Safety Attitude Score for Medium Contractors

Contractor No.	Safety Attitude Score
1	100
2	113
3	87
4	65
5	68
6	114
7	118
8	44
9	94
10	128
11	111
12	73
13	105
14	93
15	73
16	127
17	43
18	138
19	119
20	49
21	97
22	131

Continued Table 5.5

Contractor No.	Safety Attitude Score
23	115
24	57
25	147
26	97
27	114
28	113
29	63
30	117
31	123
32	128
33	88
34	61
35	39
36	118
37	107
38	115
39	97
40	123
41	112
42	113
43	132
44	49
45	83
46	125
47	92
48	79
49	81

Continued Table 5.5

Contractor No.	Safety Attitude Score
50	67
51	94
52	71
53	148
54	116
55	135
56	143
57	87

Table 5.6: Safety Attitude Score for Large Contractors

Contractor No.	Safety Attitude Score
1	73
2	137
3	126
4	118
5	142
6	52
7	78
8	113
9	100
10	109
11	133
12	63
13	123
14	132
15	129
16	142
17	97
18	85
19	152
20	94
21	117
22	136
23	106
24	115
25	114
26	121
27	95

5.3 CONTRACTOR SAFETY PERFORMANCE LEVEL

The Contractor Safety Performance Level (SPL) is a computed value used to measure contractor safety performance.

The contractor frequency rate and the contractor safety attitude score computed out of the questionnaire for each contractor were both used to compute a safety performance level for each contractor of the three sizes. The safety performance level will be calculated by the following formula:

$$SPL = SAS / FR$$

where:

SAS = the Safety Attitude Score computed out of the questionnaire for each contractor.

FR = the Frequency Rate, the number of disabling (lost-time) injuries per million employee-hours worked (10).

If the frequency rate for a contractor equals zero, then SPL will be undefined. The undefined values of SPL were replaced by a maximum value of 2 which will be used later on to calculate the safety performance level Index.

The safety performance levels for the participating contractors were calculated and are presented in Table 5.7 for small contractors, Table 5.8 for medium contractors, and Table 5.9 for large contractors.

Table 5.7: Safety Performance Level For Small Contractors

Contractor No.	Safety Performance Level
1	0.33
2	0.16
3	0.22
4	0.27
5	0.17
6	0.25
7	0.16
8	0.45
9	0.20
10	0.23
11	0.24
12	0.14
13	0.35
14	0.32
15	0.24
16	0.35
17	0.14
18	0.29
19	0.24
20	0.12

Continued Table 5.7

Contractor No.	Safety Performance Level
21	0.35
22	0.79
23	0.56
24	0.37
25	0.26
26	0.72
27	0.59
28	0.30
29	0.18
30	0.14
31	0.37
32	0.69
33	0.41
34	2.00
35	2.00
36	2.00
37	2.00
38	2.00

Table 5.8: Safety Performance Level For Medium Contractors

Contractor No.	Safety Performance Level
1	0.62
2	0.81
3	0.41
4	0.24
5	0.28
6	0.92
7	1.03
8	0.14
9	0.54
10	1.42
11	0.80
12	0.34
13	0.70
14	0.67
15	0.32
16	1.21
17	0.13
18	1.34
19	1.03
20	0.15

Continued Table 5.8

Contractor No.	Safety Performance Level
21	0.59
22	1.51
23	0.73
24	0.17
25	1.81
26	0.64
27	0.84
28	1.21
29	0.29
30	0.96
31	1.11
32	1.44
33	0.53
34	0.23
35	0.12
36	1.37
37	0.69
38	1.24
39	0.71
40	0.79
41	0.86
42	0.95
43	1.65

Continued Table 5.8

Contractor No.	Safety Performance Level
44	0.16
45	0.32
46	1.21
47	0.40
48	0.33
49	0.38
50	0.29
51	0.54
52	0.23
53	2.00
54	2.00
55	2.00
56	2.00
57	2.00

Table 5.9: Safety Performance Level For Large Contractors

Contractor No.	**Safety Performance Level**
1	0.29
2	1.52
3	1.28
4	0.93
5	1.60
6	0.16
7	0.37
8	0.94
9	0.61
10	0.80
11	1.18
12	0.23
13	1.01
14	1.07
15	1.24
16	1.60
17	0.60
18	0.45
19	1.88
20	0.57

Continued Table 5.9

Contractor No.	Safety Performance Level
21	0.99
22	1.55
23	0.66
24	0.76
25	0.69
26	0.89
27	0.53

5.4 VARIATION OF SAFETY

The Safety Performance Level Index is used as a measure of variation of safety for the different sizes of contractors.

The contractor's calculated safety performance level (SPL) was used to compute a safety performance level index for each contractor of the different sizes. Since the maximum SPL value is 2.0, the safety performance level index will be calculated as follows:

$$\text{Safety Performance Level Index} = \frac{\text{SPL x 100}}{2}$$

where:

SPL	=	Safety Performance Level value for each contractor.
2	=	Maximum Safety Performance Level Value.

The safety performance level indexes for the different sizes of contractors were calculated and are presented in Table 5.10 for small contractors, Table 5.11 for medium contractors, and Table 5.12 for large contractors.

By plotting safety performance level indexes versus different sizes of contractors, we get figure 5.1.

The safety performance level indexes for small contractors are low in general and the variation of safety performance level index is small compared to the medium and large maintenance contractors. The maximum is 39.5% (Poor), the minimum is 6% (Very poor), and the average is 16.0%. The low safety performance level indexes could be due to non-compliance with safety regulations.

The safety performance level indexes for medium contractors vary greatly. The maximum is 90.5% (Excellent), the minimum is 6.0% (Very poor), and the average is 37.7%. These differences could be due to the absence of Saudi Safety Codes, so that contractors do not have set rules and regulations that they must follow.

For large contractors, the safety performance level indexes are high in general and the average is 45%. The high safety performance level indexes could be due to having a safety administration as part of their organization and due to the use of safety codes and practices.

Safety performance level among building maintenance contractors vary with the contractor size. Large contractors have a better average safety performance level than small and medium contractors.

Table 5.10: Safety Performance Level Index for Small Contractors

Contractor No.	Safety Performance Level Index
1	16.5
2	8
3	11
4	13.5
5	8.5
6	12.5
7	8
8	22.5
9	10
10	11.5
11	12
12	7
13	17.5
14	16
15	12
16	17.5
17	7
18	14.5
19	12
20	6
21	17.5

Continued Table 5.10

Contractor No.	Safety Performance Level Index
22	39.5
23	28
24	18.5
25	13
26	36
27	29.5
28	15
29	9
30	7
31	18.5
32	34.5
33	20.5
34	100
35	100
36	100
37	100
38	100

Table 5.11: Safety Performance Level Index for Medium Contractors

Contractor No.	Safety Performance Level Index
1	31
2	40.5
3	20.5
4	12
5	14
6	46
7	51.5
8	7
9	27
10	71
11	40
12	17
13	35
14	33.5
15	16
16	60.5
17	6.5
18	67
19	51.5
20	7.5

Continued Table 5.11

Contractor No.	Safety Performance Level Index
21	29.5
22	75.5
23	36.5
24	8.5
25	90.5
26	32
27	42
28	60.5
29	14.5
30	48
31	55.5
32	72
33	26.5
34	11.5
35	6
36	68.5
37	34.5
38	62
39	35.5
40	39.5
41	43
42	47.5

Continued Table 5.11

Contractor No.	Safety Performance Level Index
43	82.5
44	8
45	16
46	60.5
47	20
48	16.5
49	19
50	100
51	100
52	100
53	100
54	100
55	100
56	100
57	100

Table 5.12: Safety Performance Level Index for Large Contractors

Contractor No.	**Safety Performance Level Index**
1	14.5
2	76
3	64
4	46.5
5	80
6	8
7	18.5
8	47
9	30.5
10	40
11	59
12	11.5
13	50.5
14	53.5
15	62
16	80
17	30
18	22.5
19	94
20	28.5
21	49.5
22	77.5
23	33
24	38
25	34.5
26	44.5
27	26.5

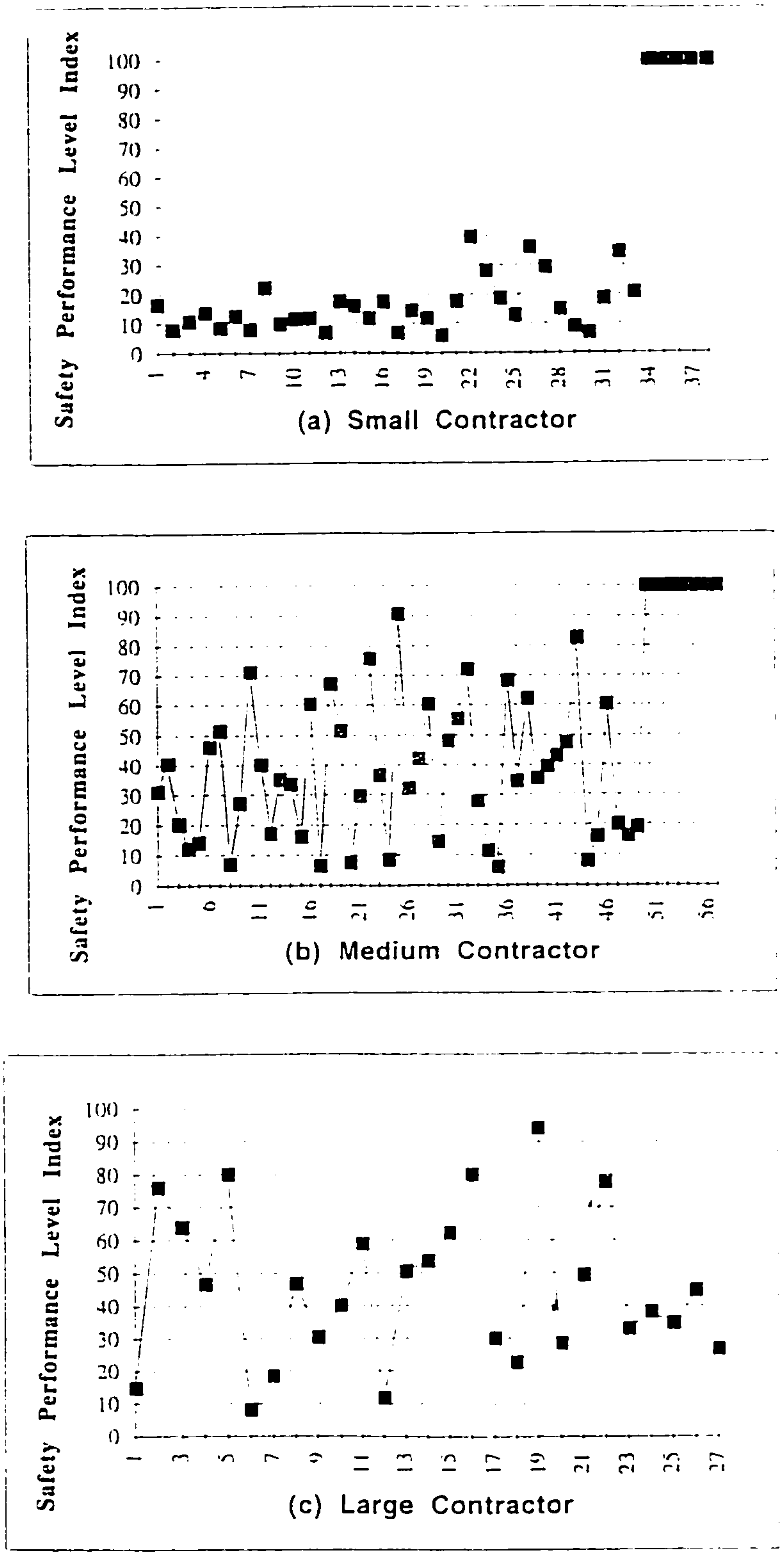


Fig. 5.1: Safety Performance Level Index for Different Sizes of Maintenance Contractors (a) Small (b) Medium and (c) Large

Table 5.13, Table 5.14, and Table 5.15 summarize the safety assessment results of the respondent maintenance contractors of the different sizes.

Table 5.13: Summary of the Safety Assessment Results for Small Contractors

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
1	234	77	0.33	16.5
2	316	51	0.16	8
3	314	68	0.22	11
4	306	83	0.27	13.5
5	310	53	0.17	8.5
6	241	60	0.25	12.5
7	281	44	0.16	8
8	208	93	0.45	22.5
9	292	59	0.20	10
10	303	69	0.23	11.5
11	255	62	0.24	12
12	310	44	0.14	7
13	224	79	0.35	17.5
14	271	86	0.32	16
15	300	72	0.24	12
16	262	91	0.35	17.5
17	348	47	0.14	7
18	271	78	0.29	14.5
19	340	83	0.24	12
20	345	41	0.12	6

Continued Table 5.13

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
21	240	83	0.35	17.5
22	149	118	0.79	39.5
23	177	98	0.56	28
24	238	89	0.37	18.5
25	247	65	0.26	13
26	161	116	0.72	36
27	183	107	0.59	29.5
28	245	73	0.30	15
29	314	57	0.18	9
30	327	46	0.14	7
31	243	90	0.37	18.5
32	152	105	0.69	34.5
33	211	87	0.41	20.5
34	0.00	129	2.00	100
35	0.00	97	2.00	100
36	0.00	81	2.00	100
37	0.00	123	2.00	100
38	0.00	126	2.00	100

Table 5.14: Summary of the Safety Assessment Results for Medium Contractors

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
1	162	100	0.62	31
2	140	113	0.81	40.5
3	212	87	0.41	20.5
4	267	65	0.24	12
5	241	68	0.28	14
6	124	114	0.92	46
7	115	118	1.03	51.5
8	305	44	0.14	7
9	174	94	0.54	27
10	90	128	1.42	71
11	139	111	0.80	40
12	212	73	0.34	17
13	151	105	0.70	35
14	138	93	0.67	33.5
15	230	73	0.32	16
16	105	127	1.21	60.5
17	336	43	0.13	6.5
18	103	138	1.34	67
19	115	119	1.03	51.5
20	325	49	0.15	7.5

Continued Table 5.14

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
21	166	97	0.59	29.5
22	87	131	1.51	75.5
23	157	115	0.73	36.5
24	343	57	0.17	8.5
25	81	147	1.81	90.5
26	151	97	0.64	32
27	135	114	0.84	42
28	94	113	1.21	60.5
29	215	63	0.29	14.5
30	122	117	0.96	48
31	111	123	1.11	55.5
32	89	128	1.44	72
33	165	88	0.53	26.5
34	265	61	0.23	11.5
35	319	39	0.12	6
36	86	118	1.37	68.5
37	155	107	0.69	34.5
38	93	115	1.24	62
39	137	97	0.71	35.5
40	156	123	0.79	39.5

Continued Table 5.14

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
41	130	112	0.86	43
42	119	113	0.95	47.5
43	80	132	1.65	82.5
44	316	49	0.16	8
45	263	83	0.32	16
46	104	125	1.21	60.5
47	229	92	0.40	20
48	237	79	0.33	16.5
49	214	81	0.38	19
50	234	67	0.29	100
51	175	94	0.54	100
52	308	71	0.23	100
53	0	148	2.00	100
54	0	116	2.00	100
55	0	135	2.00	100
56	0	143	2.00	100
57	0	87	2.00	100

Table 5.15: Summary of the Safety Assessment Results for Large Contractors

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
1	248	73	0.29	14.5
2	90	137	1.52	76
3	99	126	1.28	64
4	127	118	0.93	46.5
5	89	142	1.60	80
6	322	52	0.16	8
7	212	78	0.37	18.5
8	120	113	0.94	47
9	164	100	0.61	30.5
10	137	109	0.80	40
11	113	133	1.18	59
12	277	63	0.23	11.5
13	122	123	1.01	50.5
14	124	132	1.07	53.5
15	104	129	1.24	62
16	89	142	1.60	80
17	161	97	0.60	30
18	190	85	0.45	22.5
19	81	152	1.88	94
20	166	94	0.57	28.5

Continued Table 5.15

Contractor No.	Frequency Rate	Safety Attitude Score	Safety Performance Level	Safety Performance Level Index
21	118	117	0.99	49.5
22	88	136	1.55	77.5
23	160	106	0.66	33
24	151	115	0.76	38
25	166	114	0.69	34.5
26	137	121	0.89	44.5
27	178	95	0.53	26.5

CHAPTER 6

STATISTICAL DESCRIPTION AND CORRELATION OF SAFETY ASSESSMENT RESULTS

6.0 INTRODUCTION

The frequency rate and the contractor safety attitude score distributions were statistically analyzed to describe the variability in the data for each size of maintenance contractors. Statistical correlation was used to investigate and examine the relationship and dependencies between the frequency rates and the contractors' safety attitude scores for each size of maintenance contractors.

6.1 STATISTICAL DESCRIPTION

Statistical description is very useful in developing qualitative insights into the data distribution. Data indicate most clearly when they are organized. The main use of statistics is to deal with organizing, presenting and describing the distribution of data.

6.1.1 Frequency Tables and Histograms

One of the most common and useful ways of describing and presenting data sets is the frequency table and its corresponding graph, the histogram. A grouped or interval frequency table records how often data values fall within certain groups or intervals (Interval frequency).

The percentage frequency indicates the percentage of the total number of frequencies that is associated with data values falling within certain groups or intervals. The percentage frequency for any interval is calculated by dividing its interval frequency (f) by the total number of frequencies (N) multiplied by 100: % frequency = $(f/N) \times 100$. The percentage frequency distribution is mainly used to compare two or more frequency distributions that have very different N's. Another alternative to the frequency table is a cumulative frequency table. The interval cumulative frequency table records the total number of values within and below certain limits. The number in the interval cumulative frequency tables associated with highest data interval must equal N, the total number of interval frequencies. The percentage cumulative frequency indicates the percentage of the total number of frequencies that are associated with data values falling within and below certain groups or intervals. The percentage cumulative frequency for any interval is calculated by dividing its interval cumulative frequency (cumf) by the total number of frequencies (N) multiplied by 100: % cumf = $(cumf/N) \times 100$. The percentage cumulative frequency is usually obtained from the percentage frequency. The information presented in a frequency table can also be presented graphically in a histogram so that the height of each bar is proportional to the number of data values falling within certain groups or intervals. The histogram usually provides a more compact, organized, and understandable description of the data values distribution.

Table 6.1: Ranking of Contractors Frequency Rates (FR) and Contractors Safety Attitude Scores (SAS) in Descending Order for the Different Sizes of Contractors

SMALL		MEDIUM		LARGE	
FR	SAS	FR	SAS	FR	SAS
348	129	343	113	322	152
345	126	336	113	277	142
340	123	325	112	248	142
327	118	319	111	212	137
316	116	316	107	190	136
314	107	308	105	178	133
314	105	305	100	166	132
310	98	267	97	166	129
310	97	265	97	164	126
306	93	263	97	161	123
303	91	241	94	160	121
300	90	237	94	151	118
292	89	234	93	137	117
281	87	230	92	137	115
271	86	229	88	127	114
271	83	215	87	124	114
262	83	214	87	122	109
255	83	212	83	120	106
247	81	212	81	118	100
245	79	175	79	113	97
243	78	174	73	104	95

Continued Table 6.1

SMALL		MEDIUM		LARGE	
FR	SAS	FR	SAS	FR	SAS
241	77	166	73	99	94
240	73	165	71	90	85
238	72	162	148	89	78
234	69	157	147	89	73
224	68	156	143	88	63
211	65	155	138	81	52
208	62	151	135	-	-
183	60	151	132	-	-
177	59	140	131	-	-
161	57	139	128	-	-
152	53	138	128	-	-
149	51	137	127	-	-
0	47	135	125	-	-
0	46	130	123	-	-
0	44	124	123	-	-
0	44	122	119	-	-
0	41	119	118	-	-
	-	115	118	-	-
-	-	115	117	-	-
-	-	111	116	-	-
-	-	105	115	-	-
-	-	104	115	-	-
-	-	103	114	-	-

Continued Table 6.1

SMALL		MEDIUM		LARGE	
FR	SAS	FR	SAS	FR	SAS
-	-	94	114	-	-
-	-	93	113	-	-
-	-	90	68	-	-
-	-	89	67	-	-
-	-	87	65	-	-
-	-	86	63	-	-
-	-	81	61	-	-
-	-	80	57	-	-
-	-	0	49	-	-
-	-	0	49	-	-
-	-	0	44	-	-
-	-	0	43	-	-
-	-	0	39	-	-

Table 6.1 ranks the frequency rates (FR) and the contractors' safety attitude scores (SAS) in descending order for the different sizes of contractors. This table was used to count the number of data values falling within certain intervals.

Tables 6.2, 6.3 and 6.4 show the interval frequency, the frequency and the interval cumulative frequency distributions of the frequency rates (FR) for the different sizes of contractors. The highest frequency for small contractors was 5 for the interval FR of 310-319 and 240-249. The highest frequency for medium contractors was 5 for the interval frequency of 150-159, 130-139 and 80-89. For large contractors the highest frequency was 5 for the interval frequency of 160-169.

The information in Tables 6.2, 6.3 and 6.4 for frequency rates (FR) distributions for the different sizes of contractors is presented graphically in Figure 6.1a, 6.1b and 6.1c.

Tables 6.5, 6.6 and 6.7 show the interval frequency, the frequency and the interval cumulative frequency distributions of the contractor safety attitude scores (SAS) for the different sizes of contractors. The highest frequency for small contractors was 7 for the interval SAS of 80-89. The highest frequency for medium contractors was 14 for the interval SAS of 110-119. For large contractors the highest frequency was 5 for the interval SAS of 110-119.

The information in Tables 6.5, 6.6 and 6.7 for contractors' safety attitude scores (SAS) distributions for the different sizes of contractors is presented graphically in Figure 6.2a, 6.2b and 6.2c.

Table 6.2: Distribution of Frequency Rates (FR) for Small Contractors

Interval FR	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
340-349	3	9.10	33	100.00
330-339	0	0.00	30	90.90
320-329	1	3.00	30	90.90
310-319	5	15.20	29	87.90
300-309	3	9.10	24	72.70
290-299	1	3.00	21	63.60
280-289	1	3.00	20	60.60
270-279	2	6.10	19	57.60
260-269	1	3.00	17	51.50
250-259	1	3.00	16	48.50
240-249	5	15.20	15	45.50
230-239	2	6.10	10	30.30
220-229	1	3.00	8	24.20
210-219	1	3.00	7	21.20
200-209	1	3.00	6	18.20
190-199	0	0.00	5	15.20
180-189	1	3.00	5	15.20
170-179	1	3.00	4	12.20
160-169	1	3.00	3	9.20
150-159	1	3.00	2	6.20
140-149	1	3.00	1	3.00
Σ	33	100.00		

Table 6.3: Distribution of Frequency Rates (FR) for Medium Contractors

Interval FR	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
340-349	1	1.90	52	100.00
330-339	1	1.90	51	98.10
320-329	1	1.90	50	96.20
310-319	2	3.80	49	94.30
300-309	2	3.80	47	90.50
290-299	0	0.00	45	86.70
280-289	0	0.00	45	86.70
270-279	0	0.00	45	86.70
260-269	3	5.80	45	86.70
250-259	0	0.00	42	80.90
240-249	1	1.90	42	80.90
230-239	3	5.80	41	79.00
220-229	1	1.90	38	73.20
210-219	4	7.70	37	71.30
200-209	0	0.00	33	63.60
190-199	0	0.00	33	63.60
180-189	0	0.00	33	63.60
170-179	2	3.80	33	63.60
160-169	3	5.80	31	59.80
150-159	5	9.60	28	54.00

Continued Table 6.3

Interval FR	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
140-149	1	1.90	23	44.40
130-139	5	9.60	22	42.50
120-129	2	3.80	17	32.90
110-119	4	7.70	15	29.10
100-109	3	5.80	11	21.40
90-99	3	5.80	8	15.60
80-89	5	9.60	5	9.60
Σ	52	100.00		

Table 6.4: Distribution of Frequency Rates (FR) for Large Contractors

Interval FR	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
320-329	1	3.70	27	100.00
310-319	0	0.00	26	96.30
300-309	0	0.00	26	96.30
290-299	0	0.00	26	96.30
280-289	0	0.00	26	96.30
270-279	1	3.70	26	96.30
260-269	0	0.00	25	92.60
250-259	0	0.00	25	92.60
240-249	1	3.70	25	92.60
230-239	0	0.00	24	88.90
220-229	0	0.00	24	88.90
210-219	1	3.70	24	88.90
200-209	0	0.00	23	85.20
190-199	1	3.70	23	85.20
180-189	0	0.00	22	81.50
170-179	1	3.70	22	81.50
160-169	5	18.50	21	77.80
150-159	1	3.70	16	59.30
140-149	0	0.00	15	55.60

Continued Table 6.4

Interval FR	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
130-139	2	7.40	15	55.60
120-129	4	14.80	13	48.20
110-119	2	7.40	9	33.40
100-109	1	3.70	7	26.00
90-99	2	7.40	6	22.30
80-89	4	14.80	4	14.80
Σ	27	100.00		

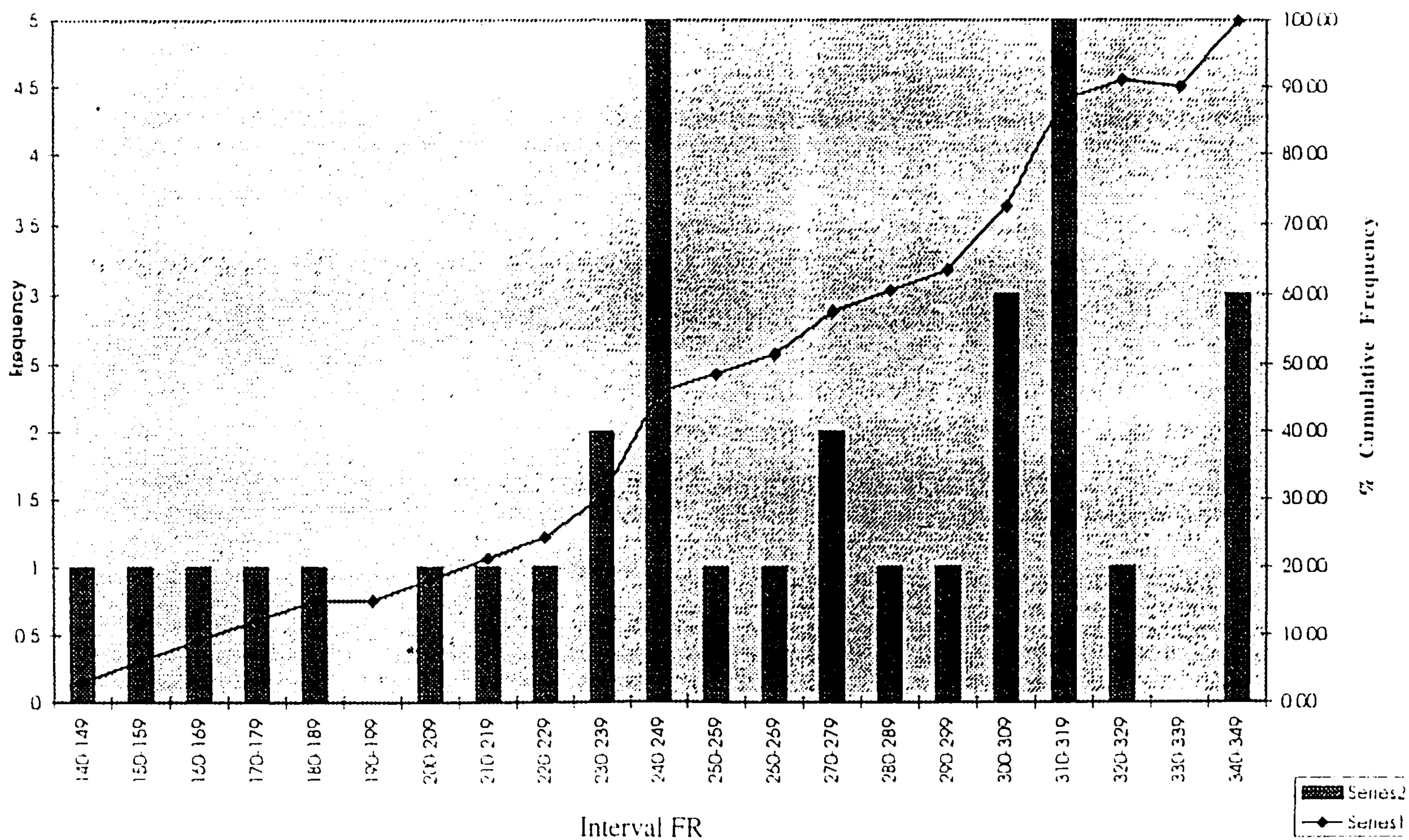


Fig. 6.1: (a) Cumulative Frequency Plot with Histogram of Frequency Rate (FR) for Small Contractors

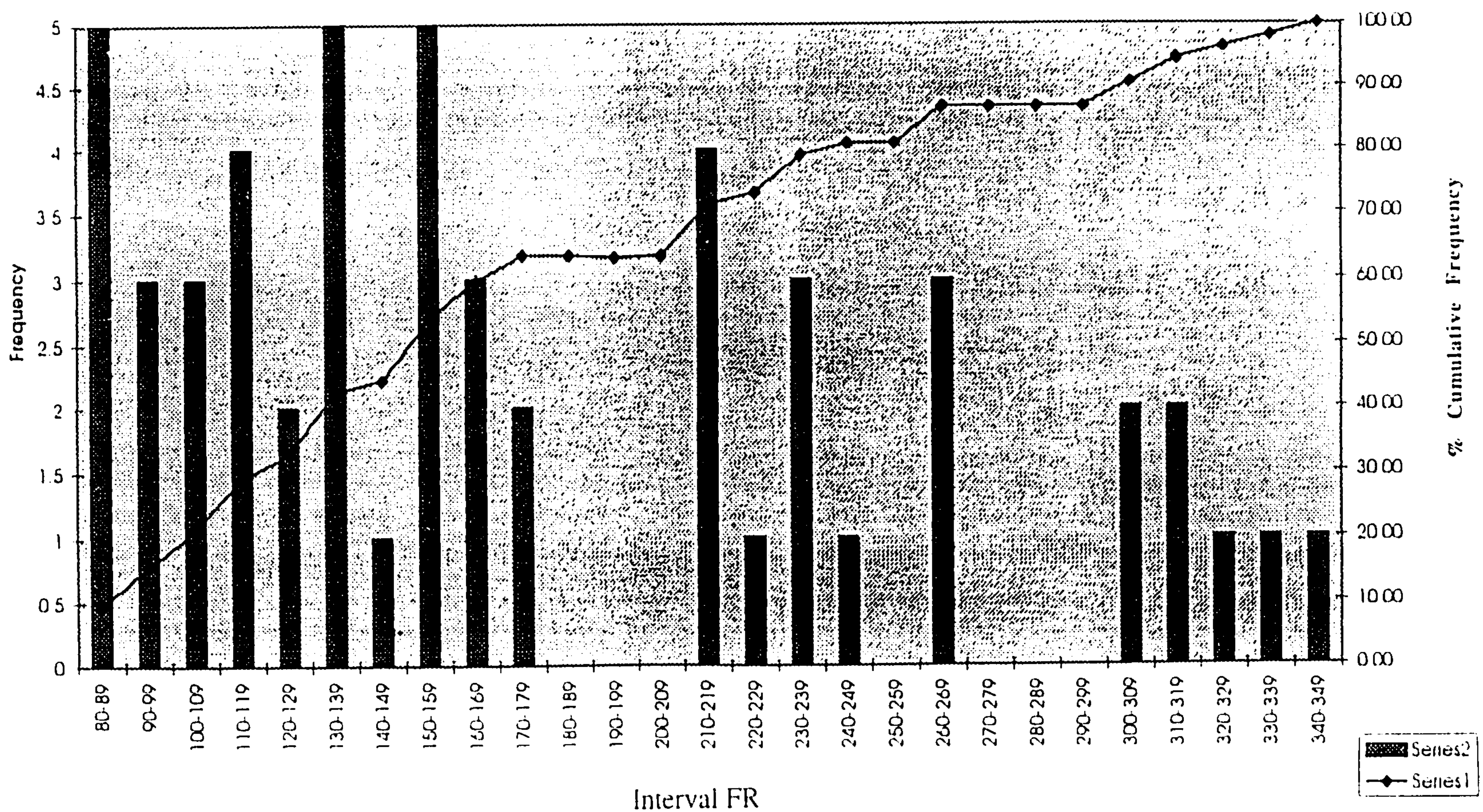


Fig. 6.1: (b) Cumulative Frequency Plot with Histogram of Frequency Rate (FR) for Medium Contractors

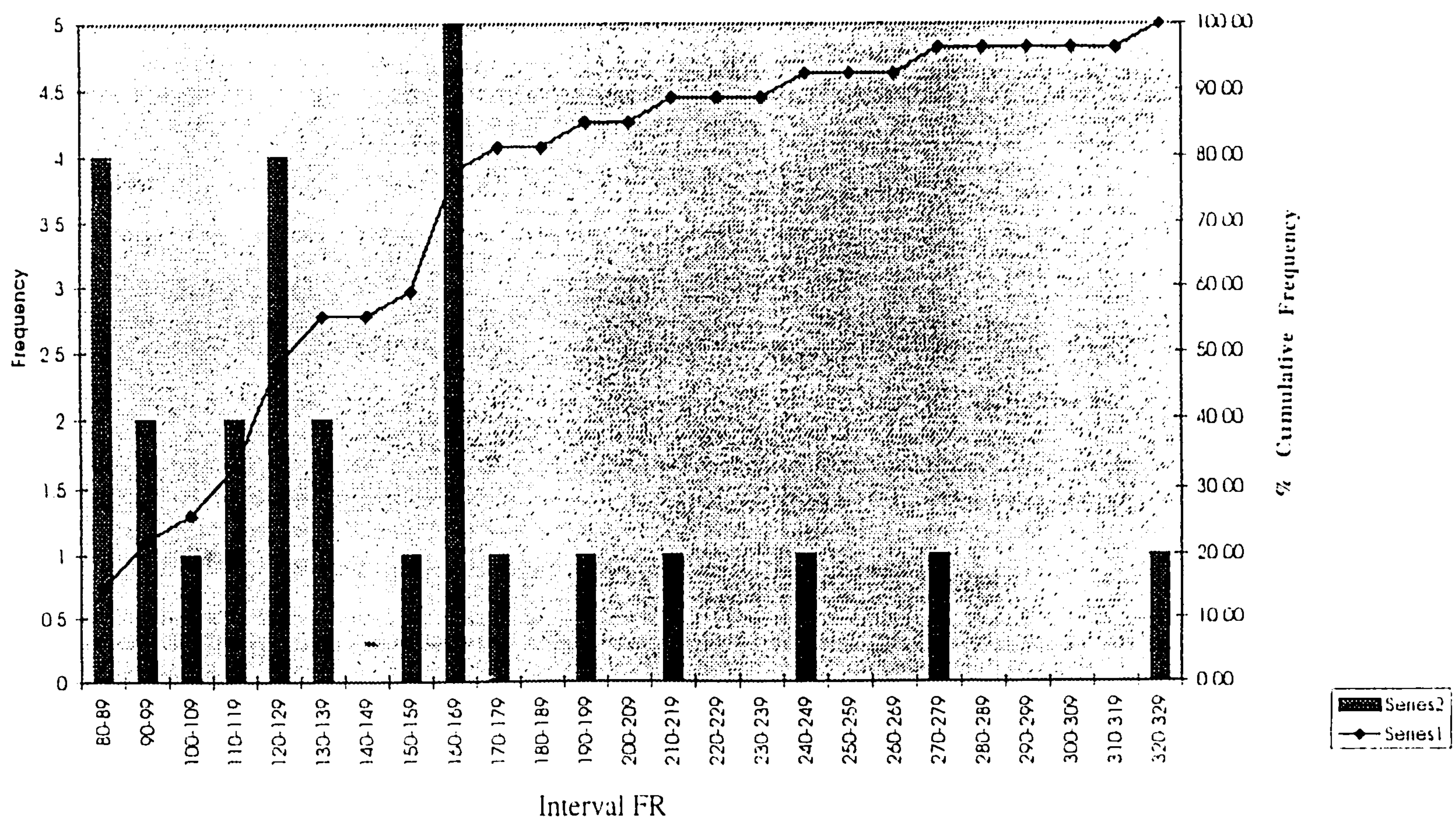


Fig. 6.1: (c) Cumulative Frequency Plot with Histogram of Frequency Rate (FR) for Large Contractors

Table 6.5: Distribution of Contractor Safety Attitude Scores (SAS) for Small Contractors

Interval SAS	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
120-129	3	7.90	38	100.00
110-119	2	5.30	35	92.10
100-109	2	5.30	33	86.80
90-99	5	13.20	31	81.50
80-89	7	18.40	26	68.30
70-79	5	13.20	19	49.90
60-69	5	13.20	14	36.70
50-59	4	10.50	9	23.50
40-49	5	13.20	5	13.20
Σ	38	100.00		

Table 6.6: Distribution of Contractor Safety Attitude Scores (SAS) for Medium Contractors

Interval SAS	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
140-149	3	5.30	57	100.00
130-139	4	7.00	54	94.70
120-129	6	10.50	50	87.70
110-119	14	24.60	44	77.20
100-109	3	5.30	30	52.60
90-99	7	12.30	27	47.30
80-89	5	8.80	20	35.00
70-79	4	7.00	15	26.20
60-69	5	8.80	11	19.20
50-59	1	1.80	6	10.40
40-49	4	7.00	5	8.60
30-39	1	1.80	1	1.80
	57	100.00		

Table 6.7: Distribution of Contractor Safety Attitude Scores (SAS) for Large Contractors

Interval SAS	Frequency	Percentage Frequency	Interval Cumulative Frequency	Percentage Cumulative Frequency
150-159	1	3.7	27	100
140-149	2	7.40	26	96.30
130-139	4	14.80	24	88.90
120-129	4	14.80	20	74.10
110-119	5	18.50	16	59.30
100-109	3	11.10	11	40.80
90-99	3	11.10	8	29.70
80-89	1	3.70	5	18.60
70-79	2	7.40	4	14.90
60-69	1	3.70	2	7.50
50-59	1	3.70	1	3.70
	27	100.00		

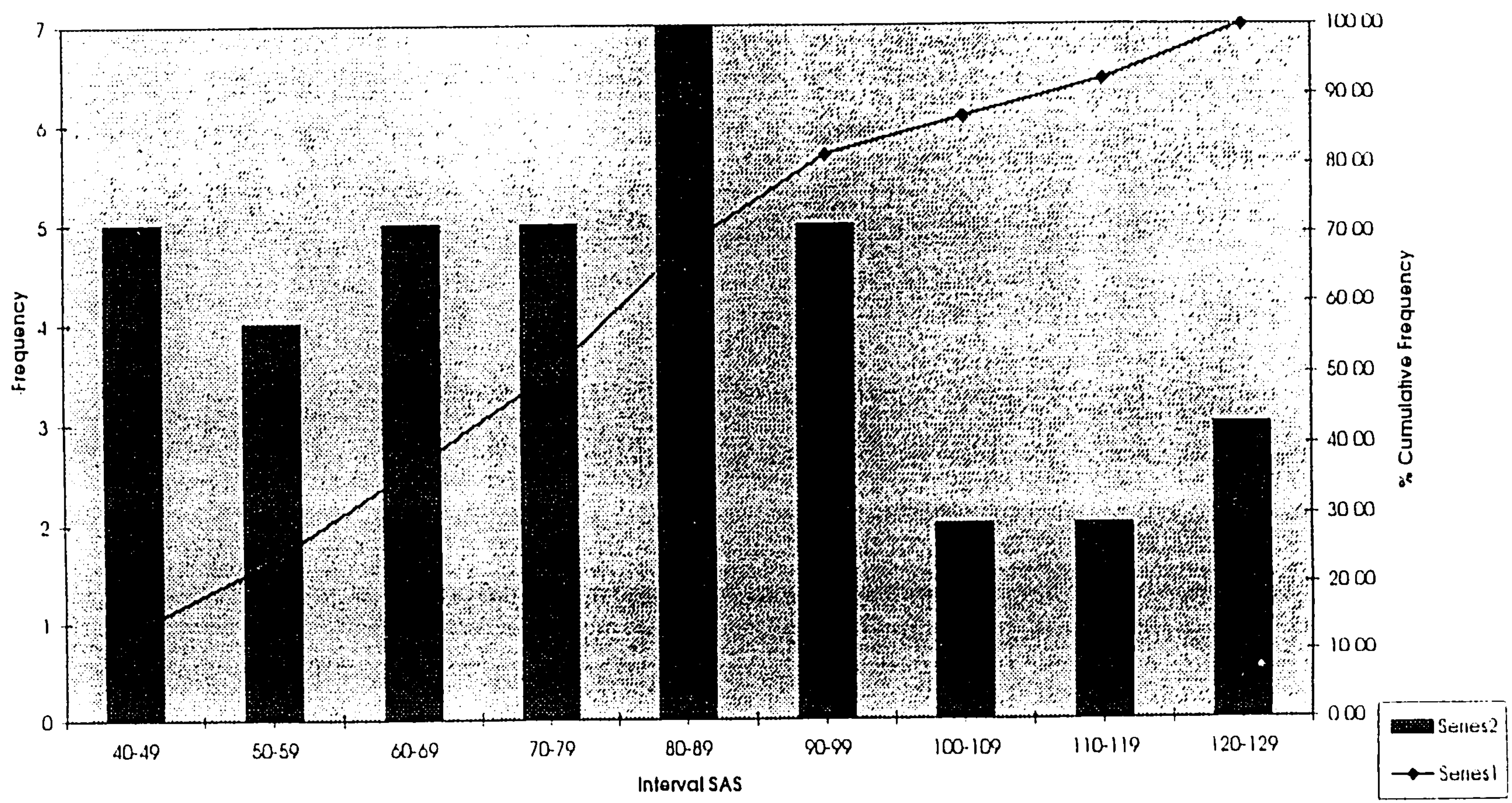


Figure 6.2: (a) Cumulative Frequency Plot With Histogram of Safety Attitude Scores (SAS) for Small Contractors

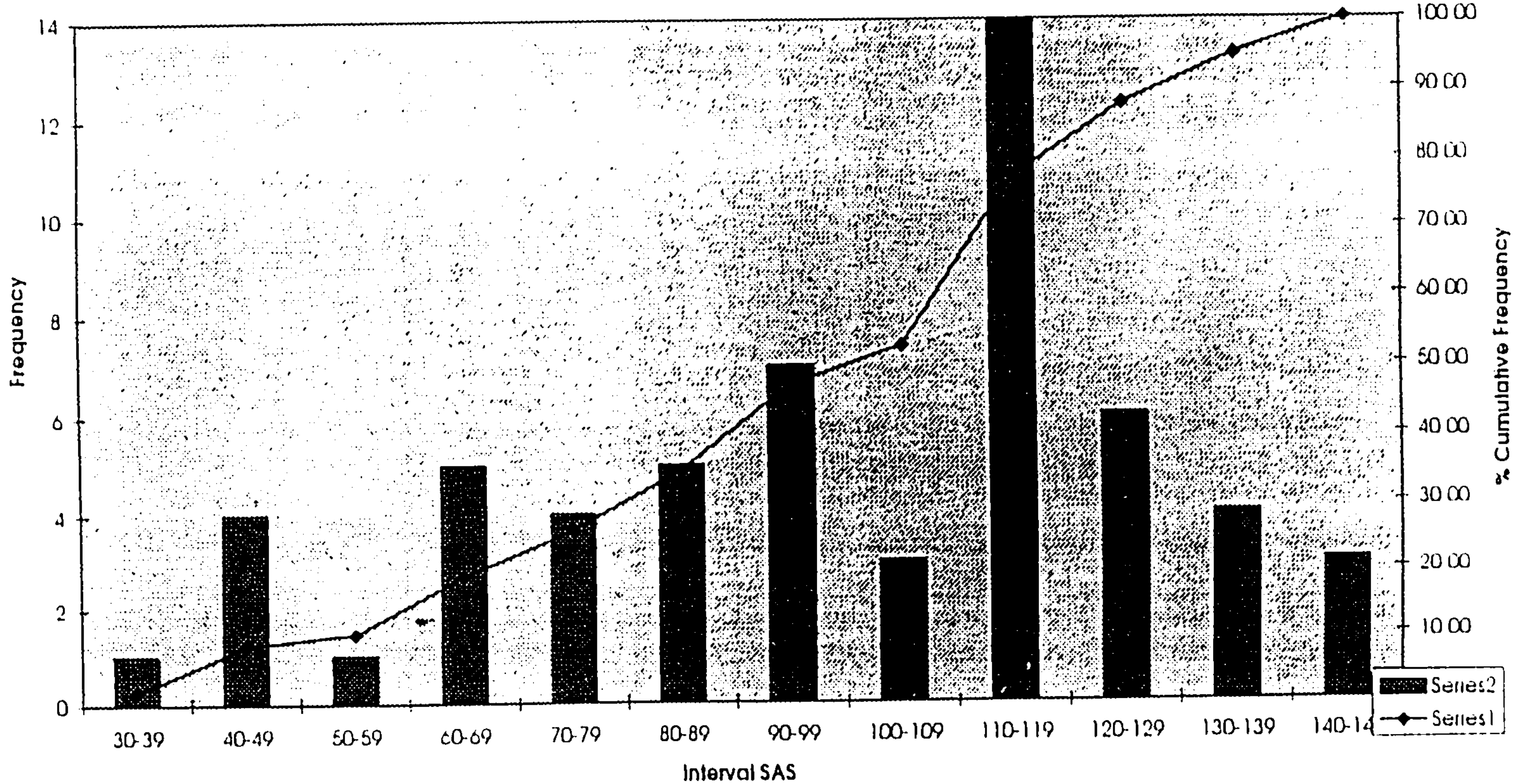


Figure 6.2: (b) Cumulative Frequency Plot With Histogram of Safety Attitude Scores (SAS) for Medium Contractors

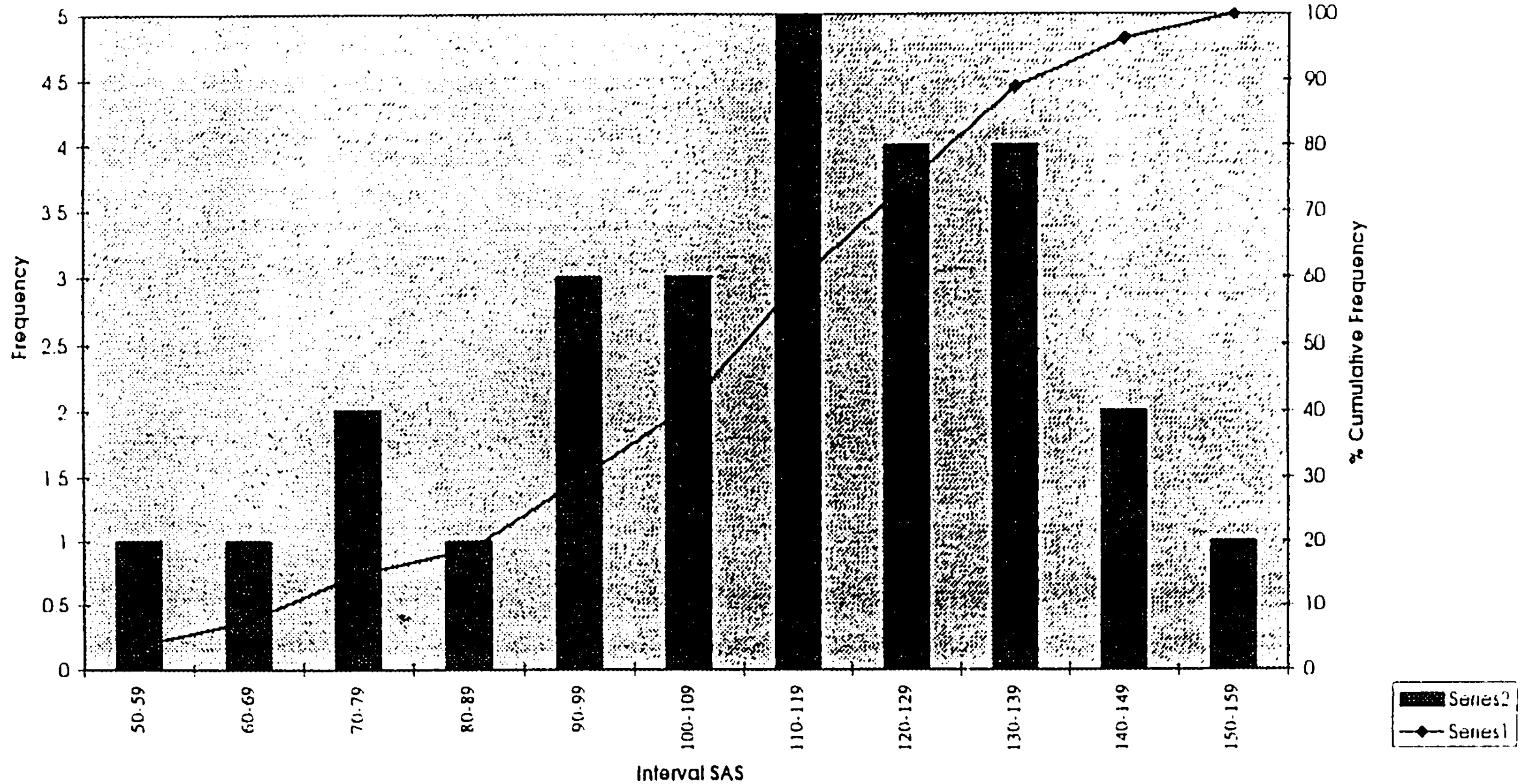


Figure 6.2: (c) Cumulative Frequency Plot With Histogram of Safety Attitude Scores (SAS) for Large Contractors

6.1.2. Summary Statistics

The important features of most histograms can be captured by a few summary statistics. The summary statistics fall into three groups: measures of location, measures of spread and measures of shape.

6.1.2.1 Measures of Location

The statistics in this group give information about where various parts of the data distribution lie. The mean, the medium, and the mode indicate where the center of the distribution lies.

a. **Mean:** The mean, m, is the balance or center point of the data distribution. It is the arithmetic average of the data values.

$$m = \frac{1}{n} \sum_{i=1}^{n} x_i \qquad \text{(Berenson, 1988)}$$

where

n = The number of data values

X_i = The data values

b. **Median**: The median, M, is the midpoint of the data values if they are arranged in order. Fundamentally, the median is a value that divides the distribution of data values into two halves, one half above the median, and one half below.

c. **Mode**: The mode is the value that occurs most frequently. It is usually represented by the tallest bar or the highest frequency on the histogram.

d. **Minimum:** The smallest value in the data set is the minimum.

e. **Maximum**: The largest value in the data set is the maximum.

f. **Lower and Upper Quartile**: The quartiles split the data into quarters. If the data values are arranged in descending order, then the quarter of the data which falls below is the lower or first quartile, Q_1, and the quarter of the data which falls above is the upper or third quartile, Q_3.

6.1.2.2 Measures of Spread or Variability

Measures of spread or variability are numbers that reflect the spread of a set of data values over the scale of measurement. All measures of variability are designed to increase in numerical value when the spread of data values increases.

a. Variance: It is the average squared deviation or difference of the data values from their mean. The variance, σ^2, is given by

$$\sigma^2 = \frac{1}{n} \sum_{i=1}^{n} (x_i - m)^2 \qquad \text{(Berenson, 1988)}$$

b. Standard Deviation: The standard deviation, σ, is simply the positive square root of the variance. The standard deviation increases as the data values in a distribution are more spread out. The standard deviation and variance are all based on deviations from the mean. Standard deviation is mainly a measure of variability.

c. Average Deviation: It is the average distance of the data values from the mean. The average deviation (AD) is based on the absolute values of the deviations from the mean. The average deviation, AD, is given by:

$$AD = \frac{\Sigma \mid x_i - m \mid}{n} \qquad \text{(Berenson, 1988)}$$

where;

n = The number of data values

$x_i - m$ = The absolute values of the deviations from the mean.

d. Total Range: It is the distance between the minimum and the maximum data values.

e. Interquartile Range: The interquartile range or IQR, is the difference between the upper, Q3, and the lower, Q1, quartiles and is given by:

$$IQR = Q3 - Q1 \qquad \text{(Berenson, 1988)}$$

The interquartile range does not use the mean as the center of the data distribution, and is therefore preferred as a useful measure of the spread of the data values if a few high values strongly influence the mean.

6.1.2.3 Measures of Shape

a. Coefficient of Skewness: Skewness refers to the manner in which the frequencies of the data are distributed on either side of the point of highest concentration on the histogram. Coefficient of skewness can be defined as:

Coefficient of Skewness

$$= \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - m)^3}{\sigma^3} \qquad \text{(Berenson, 1988)}$$

where;

Xi = is the data values

m = is the mean

σ = is the standard deviation

The sign of the coefficient of skewness is usually used to describe the symmetry. A positively skewed histogram has a long tail of data frequencies to the right, making the median less than the mean. If there is a long tail of data frequency to the left and the median is greater than the mean, the histogram is negatively skewed. If the coefficient of skewness is close to zero the histogram is approximately symmetric and the median is close to the mean.

b. Coefficient of Variation: The coefficient of variation, CV, is a statistic used primarily for distribution whose values are all positive and whose skewness is also positive. It is defined as the ratio of the standard deviation to the mean.

$$CV = \frac{\sigma}{m} \qquad \text{(Berenson, 1988)}$$

A coefficient of variation greater than one indicates the presence of a long tail of high values, and a coefficient of variation less than one reflects that the histogram does not have a long tail of high values.

6.1.3 Comparing the Assessment Results Distributions for the Different Sizes of Contractors

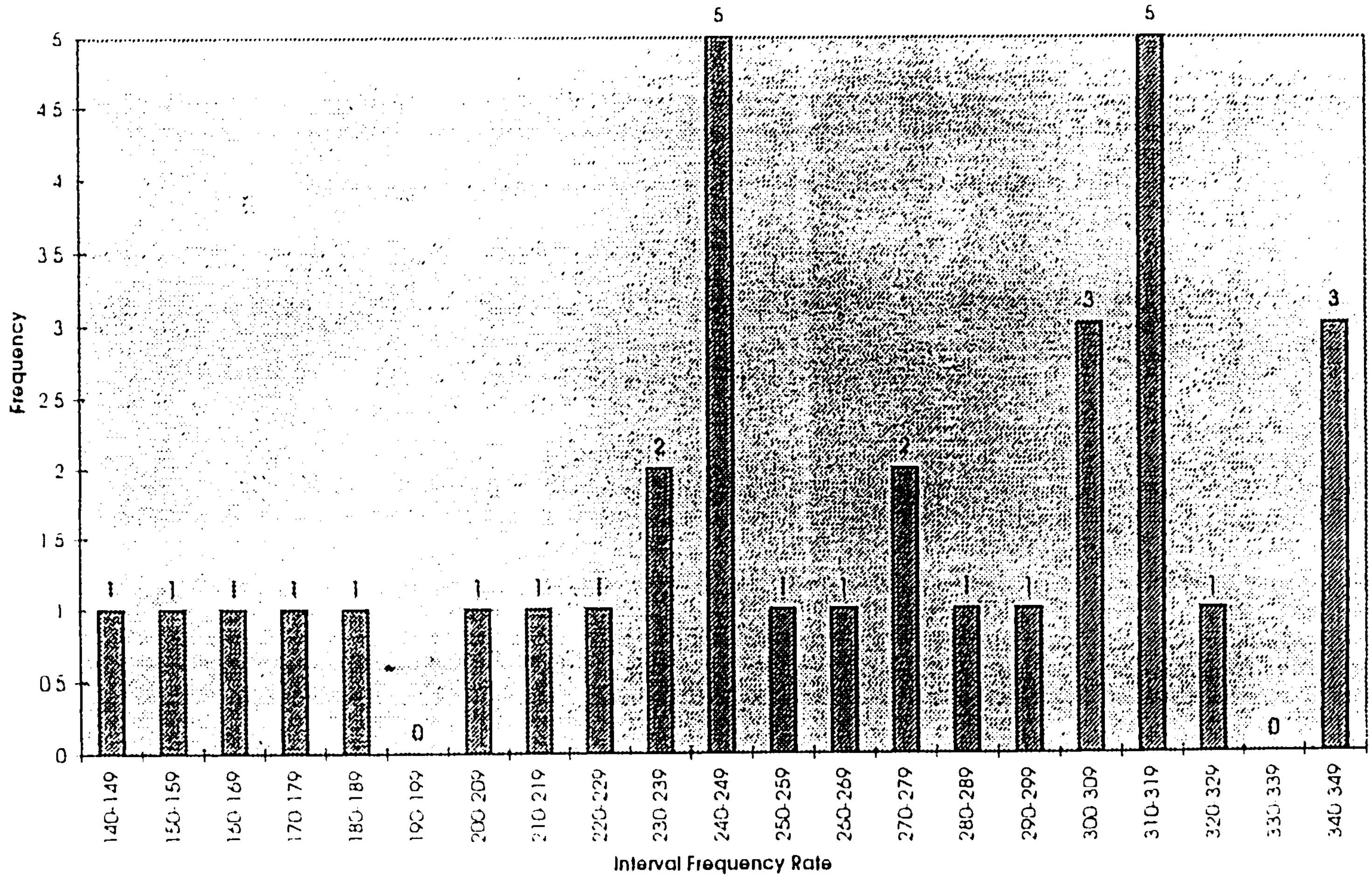
The presentation of the histograms along with summary statistics of the distributions of the frequency rates and the safety attitude scores for the different sizes of maintenance contractors reveal gross or major differences between the different distributions.

Table 6.1 shows the ranking of Frequency Rates (FR) and Safety Attitude Scores (SAS) in descending order for the different sizes of contractors. This has been used to calculate summary statistics of the different histograms for the different sizes of contractors.

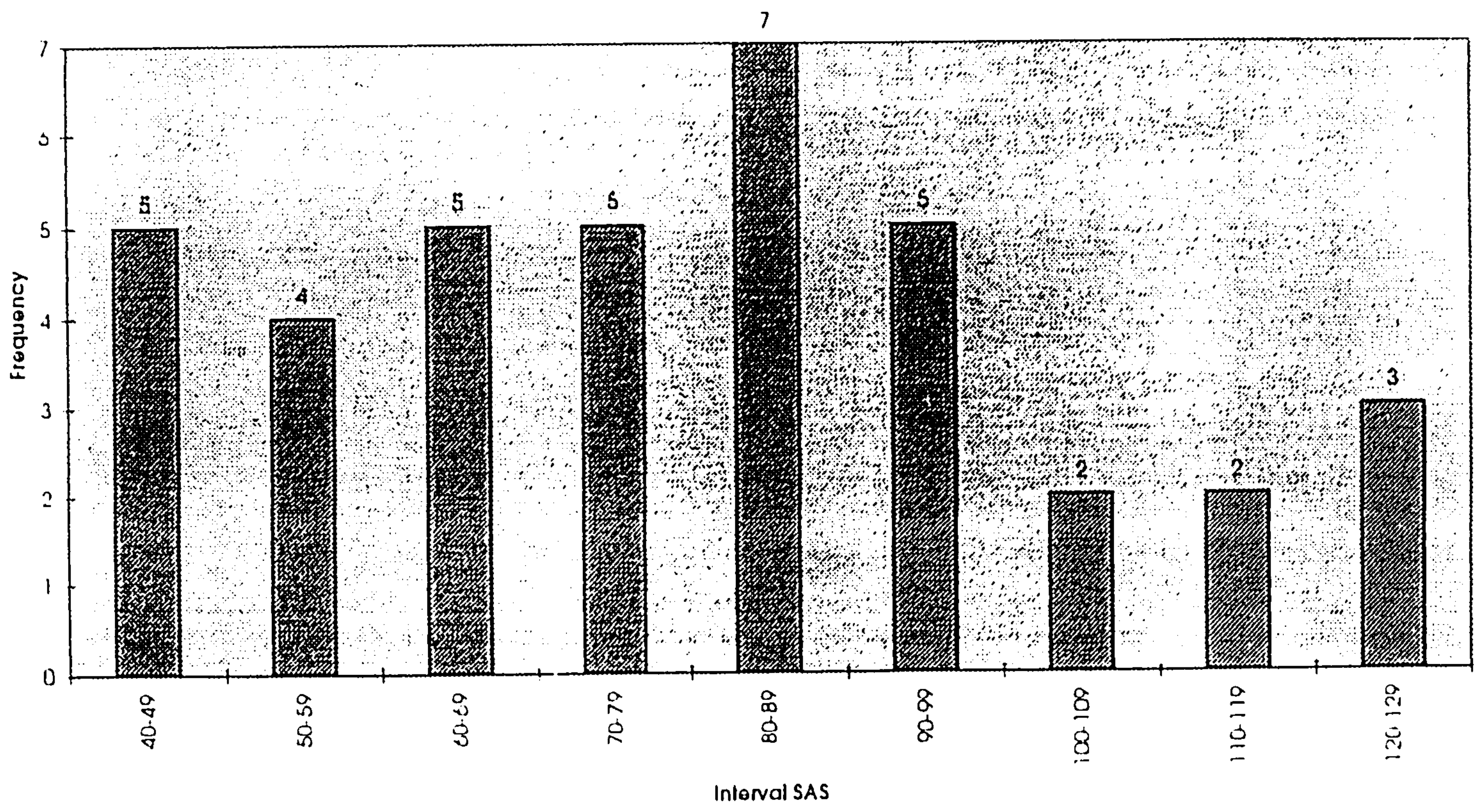
6.1.3.1 Comparing Frequency Rates and Safety Attitude Scores Distributions for Small Contractors

The histograms of the frequency rate (FR) and the safety attitude score (SAS) values shown in Table 6.1 are given in Figure 6.3, and their summary statistics are presented in Table 6.8

The frequency rates distribution is negatively skewed; the safety attitude scores distribution, on the other hand, is approximately symmetric and the median is close to the mean. Also, the frequency rate values are generally higher than the safety attitude score values, with a mean value more than three times that of the safety attitude score values. The median and standard deviation are also greater than those of the safety attitude score values.



6.3: (a) The Histogram of Frequency Rate (FR) Values for Small Contractors



6.3: (b) The Histogram of Safety Attitude Score (SAS) Values for Small Contractors

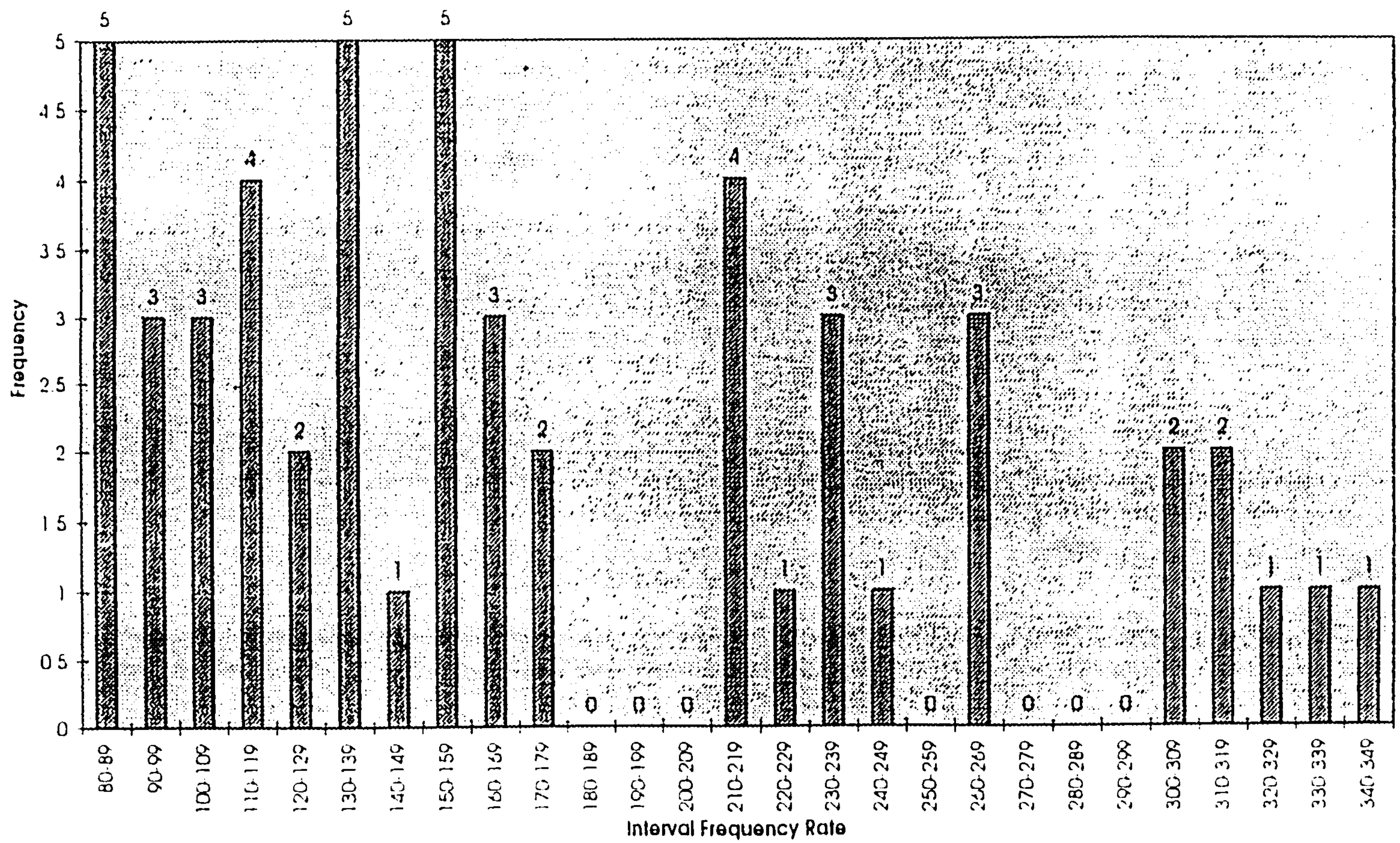
Table 6.8: Statistical Summary of the Frequency Rates (FR) and Safety Attitude Scores (SAS) Distributions for Small Contractors

Summary Statistics	**FR**	**SAS**
Number of Data Values (n)	38	38
Mean (m)	226.60	79.70
Median (M)	245.50	80.00
Mode	00.00	83.00
Minimum	00.00	41.00
Maximum	348.00	129.00
First (lower) quartile (Q_1)	188.80	60.50
Third (upper) quartile (Q_3)	304.80	92.50
Variance (ó^2)	10486.00	576.00
Standard Deviation (ó)	102.40	24.00
Total Range	348.00	88.00
Average Deviation (AD)	46.70	19.50
Interquartile Range (Q_3-Q_1)	116.00	32.00
Coefficient of Skewness	-1.20	0.30
Coefficient of Variation (CV)	0.45	0.30

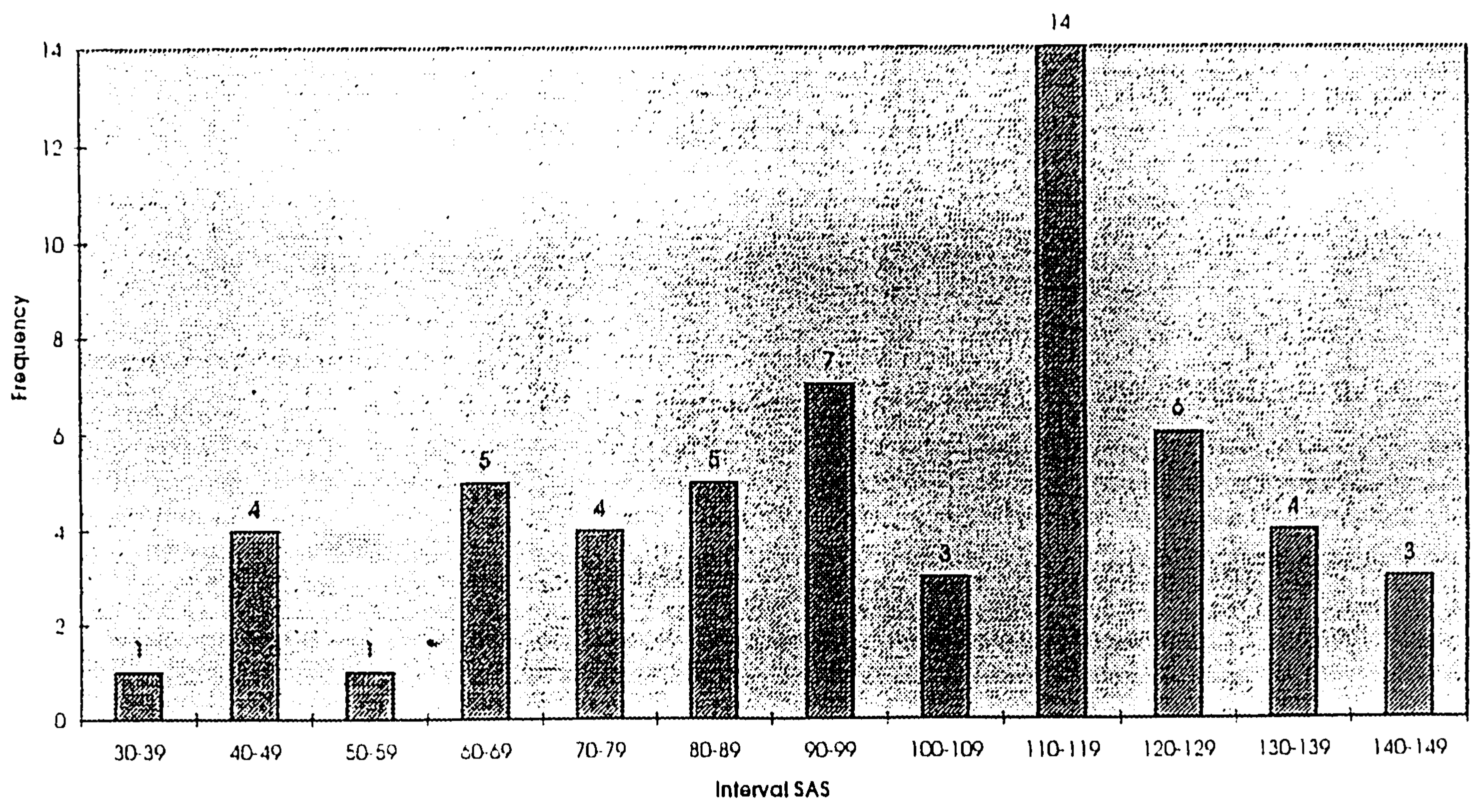
6.1.3.2 Comparing Frequency Rates and Safety Scores Distributions for Medium Contractors.

The histograms of the Frequency Rate (FR) and the Safety Attitude Score (SAS) values shown in Table 6.1 are given in Figure 6.4 and their summary statistics are presented in Table 6.9.

The frequency rates distribution is positively skewed; the safety attitude scores distribution, on the other hand, is negatively skewed. Also, the frequency rate values are generally higher than the safety attitude score values, with a mean value more than two times that of the safety attitude score values. The median and standard deviation are also greater than those of the safety attitude score values.



6.4: (a) The Histogram of Frequency Rate (FR) Values for Medium Contractors



6.4: (b) The Histogram of Safety Attitude Score (SAS) Values for Medium Contractors

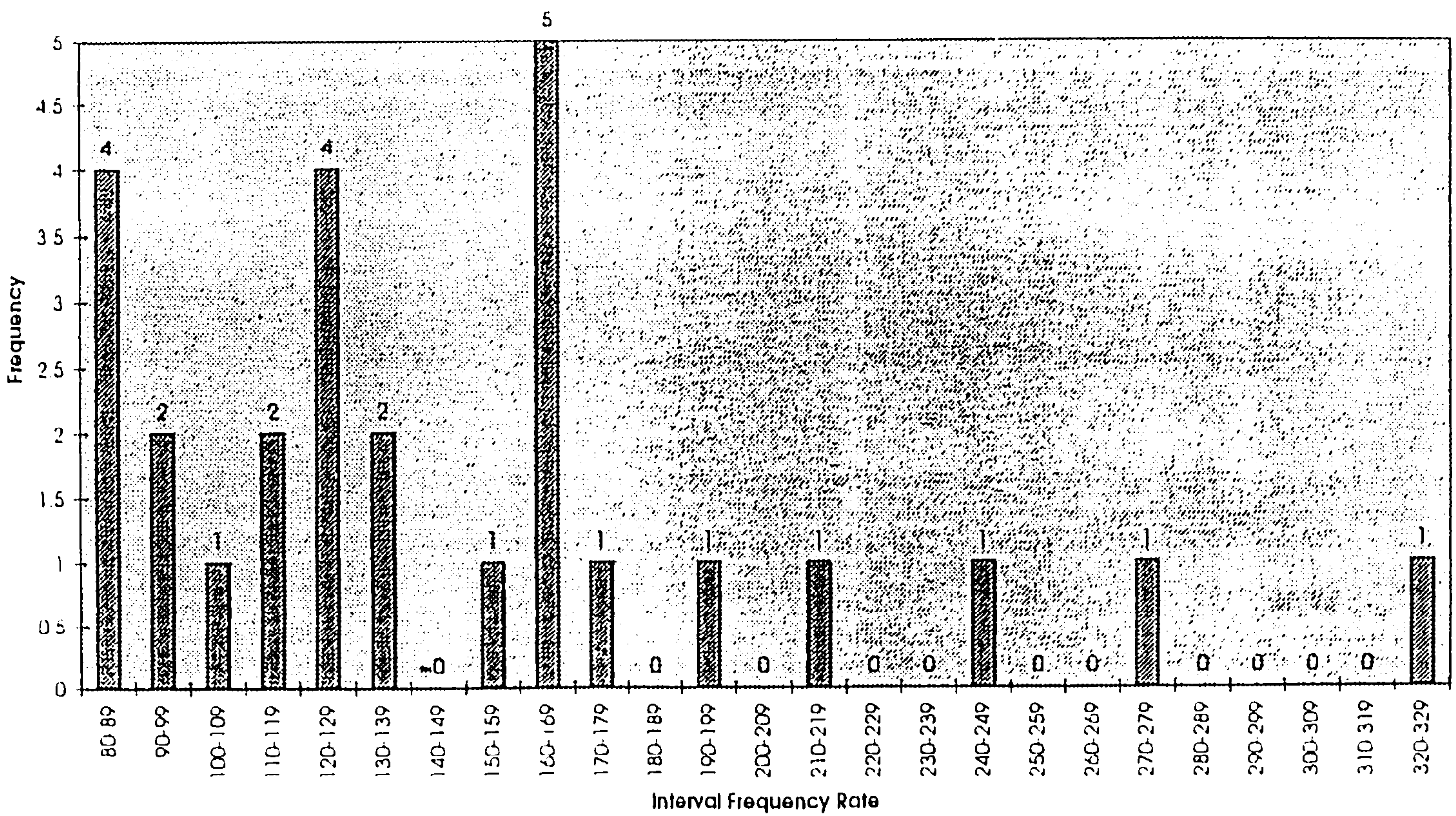
Table 6.9: Statistical Summary of the Frequency Rates (FR) and Safety Attitude Scores (SAS) Distributions for Medium Contractors

Summary Statistics	**FR**	**SAS**
Number of Data Values (n)	57	57
Mean (m)	158.80	98.90
Median (M)	145.30	103.50
Mode	00.00	113.00
Minimum	00.00	39.00
Maximum	343.00	148.00
First (lower) quartile (Q_1)	103.10	79.50
Third (upper) quartile (Q_3)	225.40	118.00
Variance ($ó^2$)	8208.30	789.60
Standard Deviation (ó)	90.60	28.10
Total Range	343.00	109.00
Average Deviation (AD)	65.40	23.50
Interquartile Range (Q_3-Q_1)	122.30	38.5
Coefficient of Skewness	0.20	-0.40
Coefficient of Variation (CV)	0.57	0.28

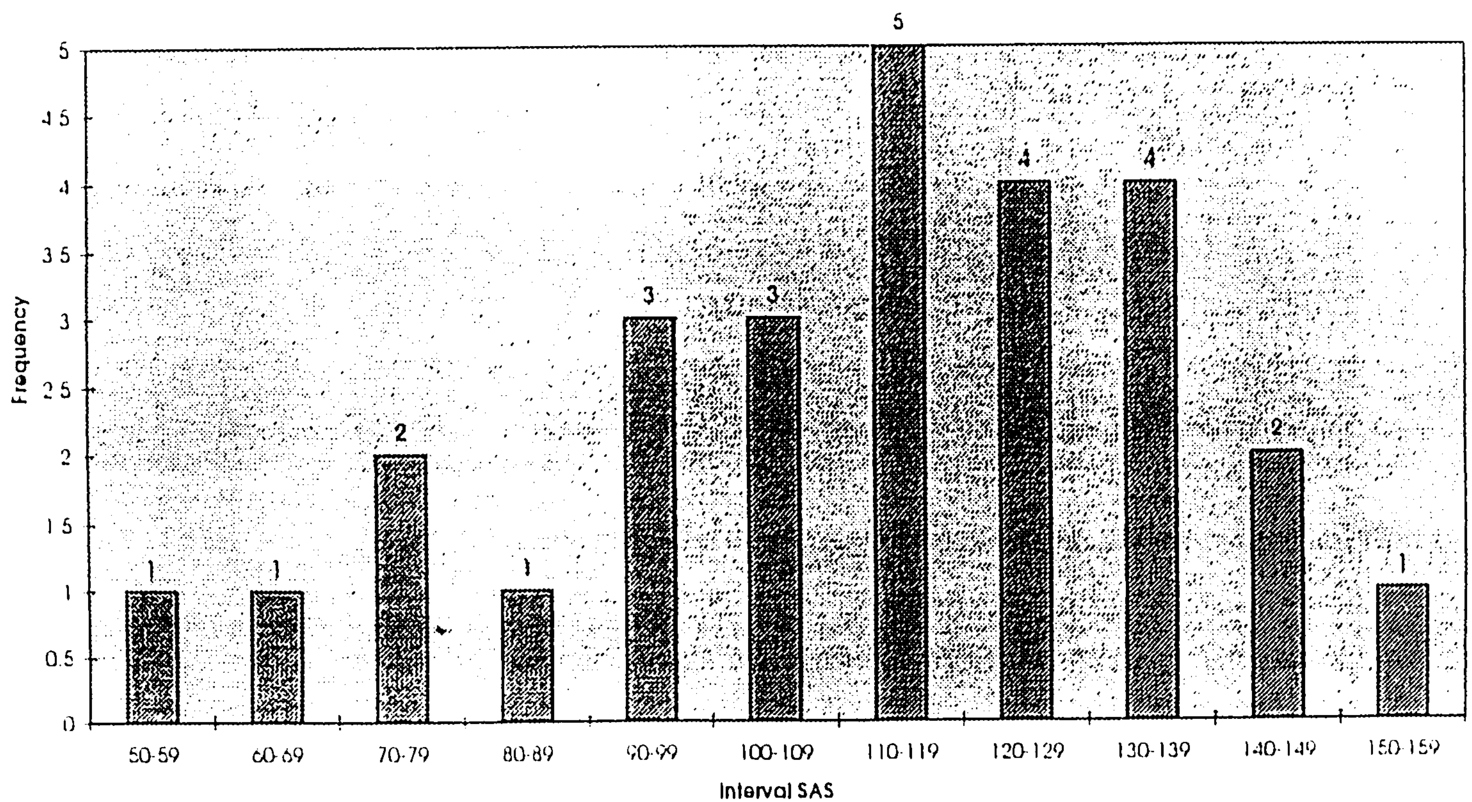
6.1.3.3 Comparing Frequency Rates and Safety Attitude Scores Distributions for Large Contractors

The histograms of the Frequency Rate (FR) and the Safety Attitude Score (SAS) values shown in Table 6.1 are given in Figure 6.5 and their summary statistics are presented in Table 6.10.

The frequency rates distribution is positively skewed; the safety attitude scores distribution, on the other hand, is negatively skewed. Also, the frequency rate values are generally higher than the safety attitude score values, with a mean value more than two times that of safety attitude score values. The median and standard deviation are also greater than those of the safety attitude score values.



6.5: (a) The Histogram of Frequency Rate (FR) Values for Large Contractors



6.5: (b) The Histogram of Safety Attitude Score (SAS) Values for Large Contractors

Table 6.10: Statistical Summary of the Frequency Rates (FR) and Safety Attitude Scores (SAS) Distributions for Large Contractors

Summary Statistics	**FR**	**SAS**
Number of Data Values (n)	27	27
Mean (m)	149.20	111.20
Median (M)	136.50	115.00
Mode	136.50	142.00
Minimum	81.00	52.00
Maximum	322.00	152.00
First (lower) quartile (Q_1)	108.50	96.00
Third (upper) quartile (Q_3)	165.80	130.50
Variance ($ó^2$)	3434.00	615.00
Standard Deviation (ó)	58.60	24.80
Total Range	241.00	100.00
Average Deviation (AD)	44.70	20.10
Interquartile Range (Q_3-Q_1)	57.30	34.50
Coefficient of Skewness	1.40	-0.60
Coefficient of Variation (CV)	0.39	0.22

6.2 STATISTICAL CORRELATION

Statistical correlation or correlational analysis is commonly used to study relations between variables in which differences in one variable may relate to differences in another variable. In conducting a correlational analysis in this study the major concern is to find how variation in frequency rates is related to variation in safety attitude scores.

6.2.1 Scatterplots

The most common display of data for correlational analysis is scatterplot or crossplot, which is an x-y graph of the data on which the x-coordinate corresponds to the value of one variable and the y-coordinate to the value of the other variable. The general shape or trend of the distribution of points in each diagram provides information about the relation between the two variables (x and y). There are three possible patterns one can observe on a scatterplot: the variables are either positively correlated, negatively correlated, or uncorrelated.

They are positively correlated if the larger values of one variable tend to be associated with larger values of the other variable, and similarly the smaller values of one variable associated with the smaller values of the other variable.

They are negatively correlated if the larger values of one variable tend to be associated with the smaller values of the other variable.

The final pattern is to be uncorrelated in which an increase in one variable has no apparent effect on the other variable.

The scatterplots of the frequency rate (FR) and the Safety attitude scores (SAS) value shown in Table 5.1 and Table 5.4 for small contractors, Table 5.2 and Table 5.5 for medium contractors, and Table 5.3 and Table 5.6 for large contractors are negatively correlated and they are plotted in Figure 6.6.

6.2.2 Correlation Statistics

6.2.2.1 Covariance

Covariance (cov or cov (x, y)) is the average of the products of deviations of two variables about their common mean:

$$\mathrm{COV} = \frac{1}{n} \sum_{i=1}^{n} (x_i - m_x)(y_i - m_y) \qquad \text{(Berenson, 1988)}$$

Covariance is usually used to determine the relationship between two variables or data sets. It is mainly a summary statistic of a scatterplot. The covariance between two variables depends on the magnitude of the data values.

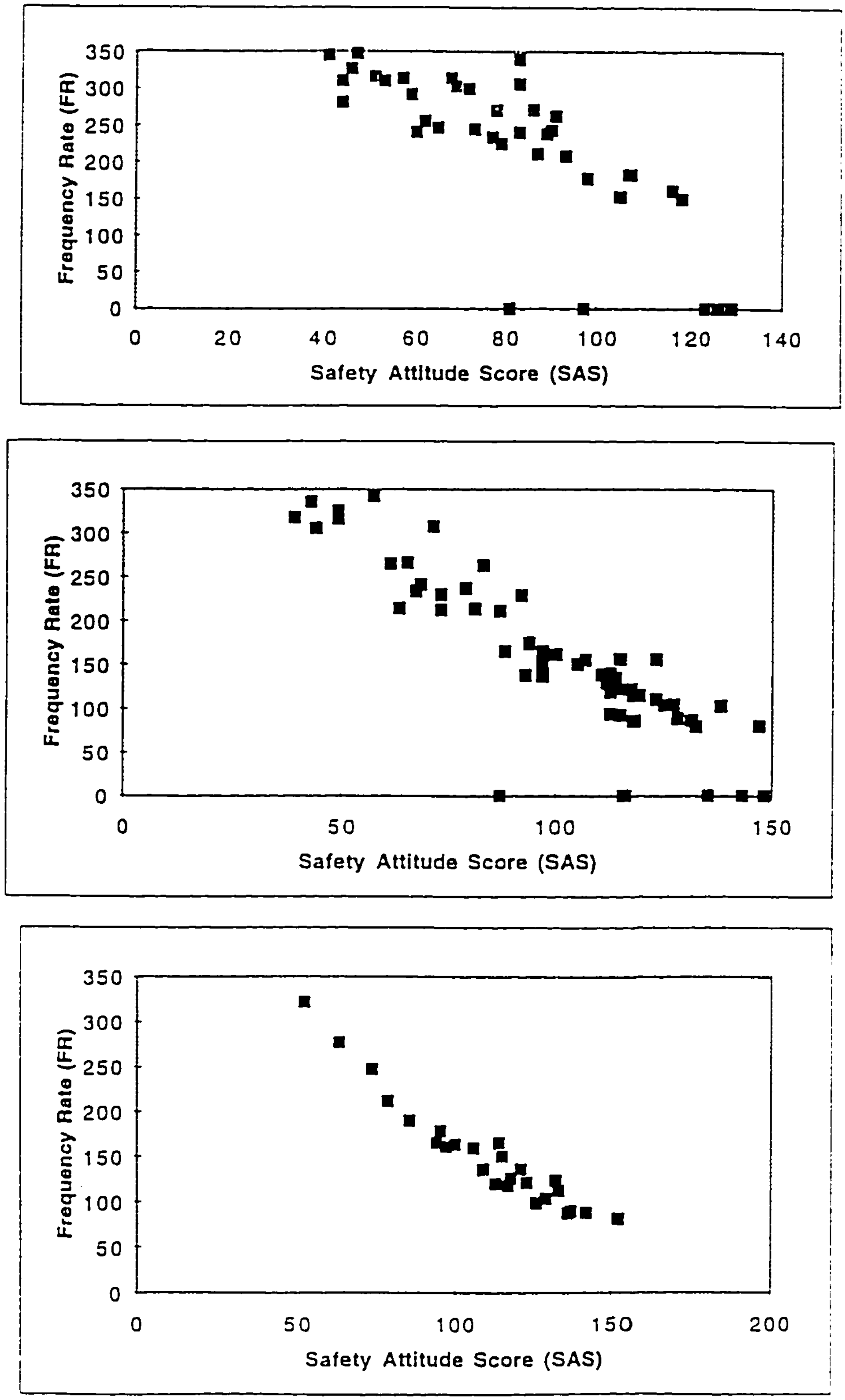


fig. 6.6 Scatter Plot for Different Sizes of Contractors

6.2.2.2 Correlation Coefficient: Pearson r

The most frequently used correlation coefficient is the Pearson Product Moment Correlation Coefficient, Pearson r ; $r=\frac{COV}{óxóy}$ (Berenson, 1988).

The correlation coefficient, r, is the statistic that is most commonly used to summarize the relationship between two variables or data sets. It is the result of dividing the Covariance (COV) by the product of the standard deviation of the x values (óx) and the y value (óx).

The correlation coefficient provides a measure of the linear relationship between two variables. It is actually a measure of how close the data values come to falling on a straight line. It ranges between -1 and +1. If r = +1 then the scatterplot will be a straight line with a positive slope. If r = -1 then the scatterplot will be a straight line with a negative slope. for $| r | < 1$ the scatterplot appears as a cloud of points that becomes fatter and more diffuse as $| r |$ decreases from 1 to 0.

The Covariance of the frequency rates and the safety attitude scores scatterplot for the small contractors is -1906.86, the standard deviation of the frequency rates is 102.40 and that of the contractor safety attitude score is 24.00. The correlation coefficient between the frequency rates and the contractor safety attitude scores, therefore, is -0.78, which means a good correlation does exist between the small contractors' frequency rates and the small contractors' safety attitude scores.

The Covariance of the frequency rates and the safety attitude scores scatterplot for the medium contractors is -2234.62, the standard deviation of the frequency rates is 90.60, and of the contractor safety attitude scores is 28.10. The correlation coefficient between the frequency rates and the contractor safety attitude scores, therefore, is -0.89. This implies the existence of a high correlation between medium contractors' frequency rates and medium contractors' safety attitude scores.

The covariance of the frequency rates and safety attitude scores scatterplot for the large contractors is -1395.05, the standard deviation of the frequency rates is 58.60 and of the contractor safety attitude scores is 24.80. The correlation coefficient between the frequency rates and the contractor safety attitude scores, therefore, is -0.96. This reflects a strong correlation between the large contractors' frequency rates and the large contractors' safety attitude scores.

The value of the correlation coefficient indicates that the highest correlation between FR and SAS was found within the large contractors.

6.2.3 Linear Regression

The value of r, the correlation coefficient, is often a good indicator of how good the prediction of one variable from the other variable is with a linear equation. If $|r|$ is large the prediction will give possible values. On the other hand, if $|r|$ is small, then knowing the value of one variable does not help in predicting the value of the other.

In linear regression the dependence of one variable on the other can be described by the equation of a straight line : y = a x + b (Berenson, 1988).

where;

a = the slope, equal to the correlation coefficient multiplied by the ratio of the standard deviations = $r \frac{\sigma y}{\sigma x}$

b = the constant or the y- intercept, can be calculated using the means of the two variables, m_x, and m_y, $b = m_y - am_x$

6.2.3.1 Prediction of Frequency Rates (FR)

For small contractors the linear regression equation for predicting the contractor frequency rate (FR) from a known contractor safety attitude score (SAS) with the following parameters; r = -0.78, σ_{FR} = 102.40, σ_{SAS} = 24.00, mean $_{FR}$ = 226.60, and mean $_{SAS}$ = 79.70, is;

$$FR = a_{SAS} + b$$

where;

$$a = r\frac{\sigma_{FR}}{\sigma_{SAS}} = (-0.78)\frac{102.40}{24.00} = -3.33 \quad \text{, and}$$

$$\begin{aligned} b = m_{FR} - a.m_{SAS} &= 226.60 - (-3.33)(79.70) \\ &= 226.60 + 265.4 \\ &= 492.0 \end{aligned}$$

$$\boxed{SAS_{small} = -3.33SAS + 492.0}$$

For medium contractors the linear regression equation, with the following parameters;

$r = -0.89$, $\sigma_{FR} = 90.60$, $\sigma_{SAS} = 28.10$, $mean_{FR} = 158.8$, $mean_{SAS} = 98.90$, $a = -2.87$, and $b = 442.6$; is;

$$\boxed{FR_{medium} = -2.87\ SAS + 442.6}$$

And for large contractors the linear regression equation, with the following parameters: $r = -0.96$, $\sigma_{FR} = 58.6$, $\sigma_{SAS} = 24.8$, $mean_{FR} = 149.2$, $mean_{SAS} = 111.2$, $a = -2.27$, and $b = 401.6$, is;

$$\boxed{FR_{large} = -2.27\ SAS + 401.6}$$

6.2.3.2 *Prediction of Contractor Safety Attitude (SAS)*

For small contractors the linear regression equation for predicting the contractor safety attitude score (SAS) from a known contractor frequency rate, with the following parameters; $r = -0.78$, $\sigma_{SAS} = 24.0$, $\sigma_{FR} = 102.4$, $mean_{SAS} = 79.70$, and $mean_{FR} = 226.6$, is;

$$SAS = a.\ FR + b$$

where;

$$a = r\frac{\sigma_{SAS}}{\sigma_{FR}} = (-0.78)\frac{24.0}{102.4} = -0.18, \text{ and}$$

$$b = m_{SAS} - a.\ m_{FR} = 79.7 - (-0.18)(226.6) = 120.50$$

$$\boxed{SAS_{small} = -0.18\ FR + 120.50}$$

For medium contractors the linear regression equation, with the following parameters; $r = -0.89$, $\sigma_{SAS} = 28.10$, $\sigma_{FR} = 90.60$, $\text{mean}_{SAS} = 98.90$, $\text{mean}_{FR} = 158.8$, $a = -0.28$, and $b = 143.36$, is;

$$\boxed{SAS_{medium} = -0.28\ FR + 143.36}$$

For large contractors the linear regression equation with the following parameters; $r = -0.96$, $\sigma_{SAS} = 24.8$, $\sigma_{FR} = 58.6$, $\text{mean}_{SAS} = 111.2$, $\text{mean}_{FR} = 149.2$, $a = -0.41$, and $b = 172.4$, is;

$$\boxed{SAS_{large} = -0.41\ SAS + 172.4}$$

Table 6.11 is a linear regression report of the correlation of the frequency rates (FR) and the safety attitude scores (SAS) for the different sizes of maintenance contractors.

Table 6.11. Linear Regression Report of the Frequency Rates(FR) and the Safety Attitude Score (SAS) for the different sizes of contractors.

	Linear Regression Equations	
	Predicting FR From Known SAS	**Predicting SAS From Known FR**
Size of Contractor	Slope, $a=r\ \frac{\text{óFR}}{\text{óSAS}}$ Intercept, $b=m_{FR}-a.m_{SAS}$ FR = a SAS +b	Slope, $a=r\ \frac{\text{óSAS}}{\text{óFR}}$ Intercept,$b=m_{SAS}-a.m_{FR}$ SAS = a FR + b
Small	a= -3.33 b= 492.0 FR = -3.33 SAS + 492.0	a= -0.18 b=120.5 SAS= -0.18 FR+120.50
Medium	a= -2.87 b= 442.60 FR = -2.87 SAS + 442.60	a= -0.28 b= 143.36 SAS = -0.28 FR+143.36
Large	a= -2.27 b=401.60 FR= -2.27 SAS + 401.60	a= -0.41 b= 172.40 SAS= -0.41 FR+172.40

6.2.4 Correlation Statistical Summary

Table 6.12 is a correlation statistical summary of the frequency rates and the safety attitude scores for the different sizes of contractors.

Table 6.12: Correlation Statistical Summary Report of the Frequency Rates (FR) and the Safety Attitude Scores (SAS) for the Different Sizes of Contractors.

Correlation Statistics	**Small**	**Medium**	**Large**
Covariance (COV)	-1906.86	-2234.62	-1395.05
Correlation Coefficient (r)	-0.78	-0.89	-0.96
Linear regression equations	FR =-3.33 SAS + 492.0	FR = -2.87 SAS + 442.60	FR =-2.27 SAS + 401.60
	SAS = - 0.18 FR+120.5	SAS = - 0.28 FR+143.36	SAS = - 0.41 FR+172.40

CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 SUMMARY

Chapter one discussed the maintenance industry and its growth in the Kingdom of Saudi Arabia and also discussed in brief the statement of the problem, study objectives, scope of work and limitations, the methodology and significance of the study.

Chapter two gave a brief overview of the previous studies. Also, it discussed the importance of the safety performance assessment factors that have been used in the survey questionnaire of this study.

Chapter three discussed the research methodology adopted in this study, methods in forming the questionnaire which has been used in this study, questionnaire description and scoring, and sample determination.

Chapter four presented the ranking of the average value for each safety factor according to the highest average rank and importance index for each of the different sizes of maintenance contractors. Also, the ranking of each safety factor is compared among the different sizes of maintenance contractors. Most of the information used in finding these results is from the surveying questionnaires which were distributed among (430) maintenance contractors of different sizes in

Saudi Arabia. The respondent contractors to the questionnaire were only 122, which represents 28% of the total sample.

In Chapter five the contractors' frequency rates and contractors' safety attitude scores were calculated. Also, the contractor safety performance level index was calculated to show the variation of safety for the different sizes of contractors.

Chapter six presented the statistical description of the frequency rates and the safety attitude scores distributions for each size of maintenance contractors. Also, statistical correlation was used to investigate and examine the relationship and dependencies between frequency rates and safety attitude scores for each size of contractors.

7.2 CONCLUSIONS

Based on the results discussed in chapters 4, 5 & 6 which present the ranking of the safety factors in Saudi Arabia and their ratings, and on the frequency rates (FR) and the safety attitude scores (SAS) and their statistical description and correlation, the following conclusions are reached:

1. Providing safety awards, top management concern in decreasing frequency rate, financial saving as a result of applying Safety and the accident costs allocation are the most important safety factors for the small maintenance contractors.

2. Top management concern in decreasing frequency rate, the use of frequency rates as a short term performance indicator and the safety consideration in the bid process are the most important safety factors for the medium maintenance contractors.

3. For the large maintenance contractors the most important safety factors are continuous practicing of safety by top management, the use of a safety program or manual, the existence of a safety professional / department, safety consideration in the bid process, and top management concern in decreasing frequency rate.

4. Kendall Concordance Analysis results and the calculated chi-square value show that small, medium, and large contractors do not agree on the ranking of the different safety factors.

5. The safety performance level indexes for small contractors are low in general and the variation of safety level is small compared to the medium and large maintenance contractors. The maximum is 39.5 % (poor), the minimum is 6.0 % (very poor) and the average is 16%. The low safety levels could be due to non-compliance with safety regulations.

6. The safety performance level indexes for medium contractors vary greatly. The maximum is 90.5 % (Excellent), the minimum is 6.0 % (Very Poor) and the average is 37%. These

differences could be due to the absence of a Saudi Safety Code, so that contractors do not have set rules and regulations that they must follow.

7. For large contractors, it can be concluded that the performance safety level indexes are high in general and the average is 45%. The high safety levels could be due to having a safety administration as part of their organization and due to the use of safety codes and practices.

8. It can be concluded that safety levels in maintenance vary with the contractor size. Large contractors have better average safety levels than small and medium contractors.

9. From the different histograms of the contractor frequency rate distributions for the different sizes of maintenance contractors the mean frequency rate for small contractors is 226.6, for medium contractors is 158.80 and for large contractors is 149.2. These indicate that the large maintenance contractors have a lower mean frequency rate value compared to the small and medium maintenance contractors.

10. From the different histograms of the contractor safety attitude distributions for the different sizes of maintenance contractors, the mean contractor safety attitude for the small contractors is 79.7, for medium contractors is 98.9, and for large contractors is 111.2. These lead us to conclude that the small and large

contractors have a higher mean contractor safety attitude than the medium contractors.

11. The correlation coefficient between the frequency rates and the contractor safety attitude scores for small contractors is -0.78, for medium contractors is -0.89, and for large contractors is -0.96. This leads us to conclude that a negative slope linear relationship exists between the frequency rates and safety attitudes, and large contractors have the highest correlation between the frequency rates and the contractor safety attitudes. This linear relationship could be a useful tool in the prediction of one variable from the other using a linear equation.

7.3 RECOMMENDATIONS

Based on the concluding remarks, the following recommendations are made:

1. The maintenance industry in Saudi Arabia should have a documented engineering standard and safety codes and procedures applicable to the maintenance of buildings and their related facilities and equipment.

2. Small and medium maintenance contractors in Saudi Arabia should learn from large maintenance contractors and take advantage of their safety experience.

3. Safety requirements on building maintenance work will save people, property and resources. Most of the Saudi Maintenance Industry is still not aware of the importance of safety in performing maintenance work. Because of that, more emphasis should be directed to safety in maintenance projects by safety officials and by owner representatives.

4. The results of this study could be used to evaluate the safety level of different sizes of maintenance contractors during the bidding process or during the contract period.

7.4 RECOMMENDED FUTURE STUDIES

The relationship between accident rates and safety attitudes of the different sizes of maintenance contractors, was discussed in this study; however, accident cost, in relation to frequency rate and safety attitude, was not discussed in this study. For this reason, it is recommended that a study be done to find out the impact of accident cost on frequency rates and safety attitudes for the different sizes of contractors.

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APPENDICES

Appendix A: Questionnaire

Name of Maintenance Contractor (optional) ______________________________

Number of disabling (lost-time) injuries during the last year:_______________

Number of workorders hours in the last year: _________________________

1. Does your firm use a safety program or manual ?

☐ Yes ☐ No

2. Does your firm have a safety professional / department?

☐ Yes ☐ No

3. Do you consider safety costs in the bid process?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

4. Does your firm have a clear management safety policy?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

5. Do you expect any financial saving by complying to safety provision?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

6. Does your firm allocate accidents costs?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

7. Does your top management concern in decreasing frequency rate?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

8. Does your top management have continuos practicing of safety?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

9. Do you use frequency rates as short term performance indicator?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

10. Do you use frequency rates in long term planning?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

11. Do you use frequency rates in determining safety objectives?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

12. Do you use frequency rates in modifying safety process?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

13. Do you use frequency rates in preventing future accidents.

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

14. Do you use frequency rates in motivating the workers ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

15. Do you use frequency rates in measuring safety accomplishment ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

16. Do you use frequency rates in determining management movements towards the desired safety objectives ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

17. Does your firm conduct safety inspections ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

18. Does your firm have a documentation of unsafe conditions ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

19. Is their a correction of unsafe conditions ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

20. Does your safety professional continuos practicing of safety ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

21. Does your safety professionals provide positive enforcement of safety rules ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

22. Does your safety professional correct unsafe conditions ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

23. Does your safety professional participate in developing safety program ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

24. Does your safety professional conduct safety meetings ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

25. Are accident reports sent to the top management ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

26. Are accident reports sent to the social insurance ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

27. Are accident reports sent to the owner representative ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

28. Does your firm provide safety award ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

29. Does your firm have any procedure for hazards recognition and control ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

30. Does your firm perform periodic hazard review ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

31. Does your firm provide orientation program for new employees ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

32. Does the orientation program provide instrucitons on personal protective equipments ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

33. Does the orientation program provide instructions on safe work practices ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

34. Does the orientation program provide instructions on emergency procedures ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

35. Does orientation program provide instrucitons on firs aid procedures ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

36. Does the orientation program provide instrucitons on accident investigation ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

37. Does the orientation program provide instruction on fire protection and prevention ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

38. Does your firm provide safety training ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

39. Do your firm conduct safety meetings for safety professionals ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

40. Does your firm perform foreman safety training ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

41. Does your firm perform accident analysis and investigation

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

42. Does your firm practically apply previous accident investigation findings in preventing future accidents ?

☐ Always ☐ Most of the times ☐ Sometimes ☐ Rarely ☐ Never

Appendix B Critical values for the Kendall of concordance W

n = 3		
K	P=0.05	P=0.01
8	0.376	0.522
9	0.333	0.469
10	0.3000	0.425
12	0.250	0.359
14	0.214	0.311
15	0.2000	0.291
16	0.187	0.274
18	0.166	0.245
20	0.150	0.221

	n = 4		n = 5		n = 6		n = 7	
k	P=0.05	P=0.01	P=0.05	P=0.01	P=0.05	P=0.01	P=0.05	P=0.01
3	-		0.716	0.840	0.660	0.780	0.624	0.737
4	0.619	0.768	0.552	0.683	0.512	0.629	0.484	0.592
5	0.501	0.644	0.449	0.571	0.417	0.524	0.395	0.491
6	0.421	0.553	0.378	0.489	0.351	0.448	0.333	0.419
8	0.318	0.429	0.287	0.379	0.267	0.347	0.253	0.324
10	0.256	0.351	0.231	0.309	0.215	0.282	0.204	0.263
15	0.171	0.240	0.155	0.211	0.145	0.193	0.137	0.179
20	0.129	0.182	0.117	0.160	0.109	0.146	0.103	0.135

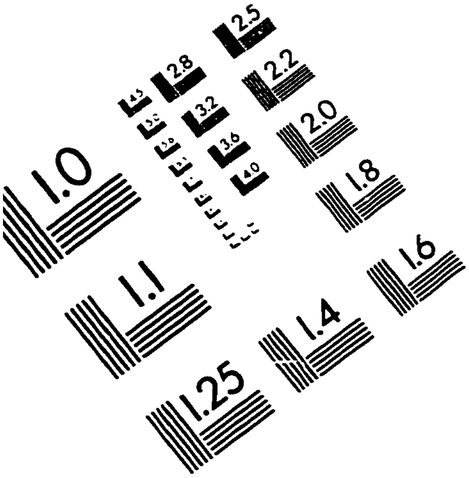
Source: Kaming (1996)

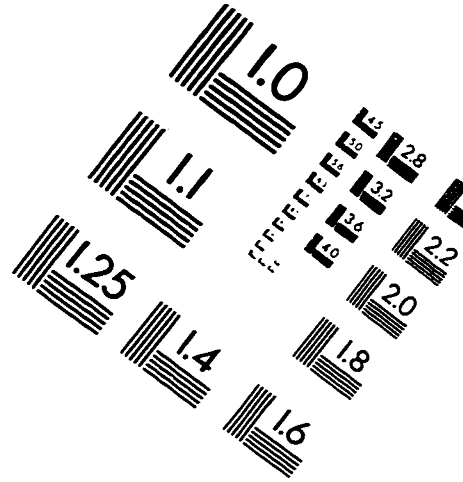
Appendix C: Critical Values of the Chi-square distribution (χ^2_c)

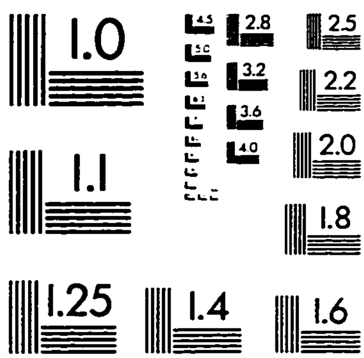
DF	P = 0.05
1	3.84
5	11.07
10	18.31
20	31.41
30	43.77
40	55.76
41	56.94

Source: Berenson (1988)

IMAGE EVALUATION TEST TARGET (QA-3)







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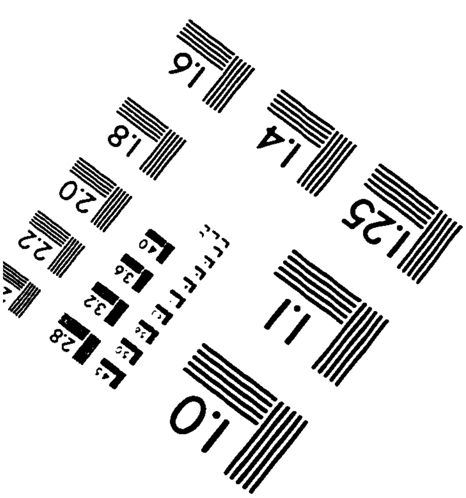

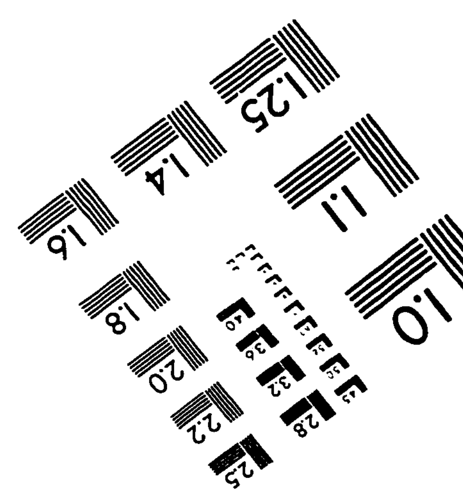

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